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Impact of M2M communications and non-M2M mobile data applications on mobile networks

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Summary

Machine-to-Machine (M2M) communications is a rapidly growing area with the potential to significantly affect mobile telecommunication networks. M2M communications encompasses a number of areas where devices are communicating with each other and without human involvement.

Machine Type Communications (MTC) devices are proliferating and expected to be two or more orders of magnitude more numerous than voice only devices. Data intensive applications running on mobile devices are similarly growing very rapidly. Similarly, "smart phones" (e.g., Apple iPhone, Samsung Galaxy, etc.) are growing rapidly in availability and popularity. The applications which run on these devices are becoming both numerous and popular and the associated data traffic is growing rapidly.

The first part of this technical paper is intended to cover both the impact of, and how to deal with, the demands of a wide variety of MTC devices. Examples are utility meters, transportation and logistics tracking and monitoring systems, building structure sensors, environment monitoring, security systems, etc. Their communication needs range from a few bytes at long intervals to on demand full motion video and audio.

The second part of this technical paper will cover the impacts of and how to deal with "smart phones." The Mobile Data Applications that run on these devices have a wide variety of communication needs ranging from none to high data rate streaming. Some of these are clearly visible to the user. For others, the user may be entirely unaware of the communications supporting the applications, such as application data update, push, synch, etc., but the mobile network operator must, of course, deal with this traffic. This part looks at the demands placed on mobile networks both by the applications on smart devices where the user is aware, and those where the user is unaware.

While the data traffic volume and the number of devices involved in MTC and “smart phones” are initially a growing concern in the leading mobile network markets, they will quickly become important everywhere. There have been several references to this non-voice communications growth as a "data tsunami." It is important to understand the nature of the changes in traffic and the subscriber base, and to have means to manage these changes.

Keywords

M2M, Machine-to-machine communication, mobile networks

Change Log

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1 Introduction

Machine-to-Machine (M2M) communications, also known as Machine Type Communication (MTC), is a rapidly growing area with the potential to significantly affect mobile telecommunication networks.

M2M communications encompasses a number of areas where devices are communicating with each other without human involvement. These can be approximately separated into two main areas. One is where machines communicate with each other autonomously and not in response to human stimulus. Examples here are environmental sensors, metering of utilities among many others. The other is where they communicate with each other in response to human stimulus, even if the human involved is unaware that it is occurring. The main example here is so-called "smart phones" which run applications in the background to synchronize data and provide other services where, in many cases, the use is unaware that these activities are taking place. Examples in both areas are examined in more depth in later sections of this document.

The following paragraphs briefly describe some basic concepts in communications that are relevant to the examination of M2M communications and the functioning of "smart phones."

An essential and basic concept that needs to be kept in mind is that of what a "user," human or otherwise, is. A "user" uses "user equipment" (UE) to communicate with another "user." The network operator provides the communication resources enabling the "users" to exchange information, and may provide additional services intended to enhance the provision of these communication facilities. The architectural modelling of communications identifies a "user plane" over which users exchange information in general transparent to the network, and a "control plane" which is used to pass information among instances of user equipment and network nodes to control the provision of resources to enable a "user plane" interaction to occur. Control plane messages are often referred to as "signalling."

The "users" in a communication instance may be humans or machines or both. For human users talking to each other, the communication path or user plane carries voice. Whether the voice is analogue or digital, circuit-switched or packet switched, is immaterial as the users are not and need not be aware of the underlying technology. For machines communicating with each other, a parallel statement can be made, although it is generally the case that digital communication is preferable, and in many cases packet switching is more appropriate than circuit switching.

There are some situations where a certain degree of confusion may arise. For human users, a centralized voice messaging system provided by the operating company is often thought of as part of the network, but it is in fact another user of the network. Control plane signalling is required to connect to it. A similar situation applies to machines except that we normally refer to these centralized devices as "servers." Whether the voice messaging system or the server is provided by a third party is a matter of who "owns" the device, not how it operates.

2 Scope

This technical paper is intended for staff of mobile network operators who wish to know more about the topic of machine to machine communications, what impacts they might expect on their networks, and what steps they can take to deal with these impacts. “Smart phones” are a specific type of user equipment that has many of the characteristics of machine-to-machine communications, and therefore many of the same types of effects on networks. In general, both fixed and mobile network operators are very familiar with voice services, but less so with data services. Similarly, network operators are very familiar with human users, but less so with non-human “users.”

Machine–to-machine communications are a reality today, and will continue to grow rapidly. M2M has the potential to cause serious disruption in mobile operator networks, and knowledge of the nature of the demands M2M communications are placing and will place on networks, and how to address and mitigate these effects, is essential to providing good service to all users. The objective of this technical paper is to make the reader better informed about machine-to-machine communications, what their requirements are, what the potential effects on networks are, and what steps may be taken to address these effects.

3 Terminology

A number of terms are being used to describe machine-to-machine communications. The more common ones are "M2M" which stands for Machine-to-Machine, and "MTC" which stands for Machine type Communications. ITU-T uses the term "Ubiquitous Sensor Network" (USN) to describe the overall system.

In this technical paper, "M2M communication" is the preferred term.

4 Trademarks, Product Names, etc.

In this technical paper, there are many references to more or less widely known and used products. In many cases, these products and services have trademarked or otherwise registered names. In all cases, ownership of the trademarks, etc., remains with the relevant company or organization.

Considering the purpose of this technical paper, it is impractical to "genericize" every instance of a product or group of products. It should, therefore, be clearly understood that mention of any product in this technical paper does not constitute an endorsement of it, positive or negative, nor should any other conclusion be drawn from the product being included here, nor should the data quoted be used as a mechanism for ranking these devices. For purposes of this technical paper, these devices should be considered essentially equivalent.

5 Setting the Context I – Humans Involved

Before we delve more deeply into machine-to-machine communications, it will be beneficial to look at the larger picture of what is happening as communications technology evolves and as society evolves with it.

Since early in this millennium, there have been assertions that:

- Most people can't do without their mobile phones
- Content is on DVDs, magazines, books, local hard-disks
- Contact Lists are by application, device, and individual situation

This assertion is followed by the prediction that very soon:

- Everyone is connected and can't do without being on-line
- The first place people go for content is on-line

And then the prediction is that in the not very distant future:

- Everyone and everything is connected all the time, everywhere
- The only place people go for content is on-line

Are these predictions proving valid? Let's look at where we are.

5.1 Can we do without our mobile phones?

The reader is likely well aware of the astonishing progress that has been made in mobile communications in just over two decades. This technical paper will not review the very interesting history of this field but will instead take a look at where we are today.

Mobile phone penetration as recently as 2008 was nominally 50% of the global population [1]. In July 2010, the BBC reported that there are five billion mobile phones and included a quote with respect to the UK: "…almost every adult, child and domestic pet seems to have one, given that 30 million phones are sold every year in the UK" [2]. To put this into perspective, it may be noted that the UK has over 80 million mobile phone subscriptions and while the population is 62.7 million (July 2011 estimate) [3] which indicates that the average person in the UK has more than one mobile phone subscription and that the average person in the UK buys a mobile phone approximately every twenty-four months. Of course, some adjustment needs to be made for the very young as well as other groups who cannot purchase mobile phones, i.e., people in long term care and other situations where they are not able to participate in what are routine activities for most. Nevertheless, it is very clear that people in the UK can't do without their mobile phones.

Despite these numbers, there are fifteen countries with higher ratios of mobile phones in use to population. Wikipedia provides a list of fifty-seven countries sorted by the number of mobile phones in use [4] and includes a column for penetration. Sorting this table by the penetration percentage indicates that, as of December 2011, no less than fifteen countries exceed the penetration rate of the UK. It is also interesting to note that forty-five of the fifty-seven countries show penetration rates in excess of eighty per cent. Finally, as with all statistics, the numbers should be treated with a little scepticism, especially as the growth is so high, and there are a number of factors that will skew the results, such as those already mentioned as well as affordability for countries where the average income is significantly below the world average. (One should always keep in mind that statistics should always be treated as suspect, not only because the same statistic from different sources often has different values, but also because of the ways that statistics can be presented to alter their perception [5] [6].)

By the end of 2010, there were 5.3 billion mobile phones. It is generally presumed that the world population hit the 7 billion mark on or about 31 October 2011 [7]. The following table along with a number of other relevant statistics are available from [8]. Of direct interest for this technical paper is that smart phone shipments in 2010 were about 300 million and are expected to be over 450 million in 2011 and to significantly exceed 600 million by 2015 clear indication that this category of user equipment will play a significant role in the nature of traffic carried on mobile operators' networks.

Table 1 – Key Global Telecom Indicators for the World Telecommunication Service Sector in 2010 (All figures are estimates)

	Global	Developed Nations	Developing Nations	Africa	Arab States	Asia & Pacific	CIS	Europe	The Americas
Mobile cellular subscriptions (millions)	5,282	1,436	3,846	333	282	2,649	364	741	880
Per 100 people	76.2%	116.1%	67.6%	41.4%	79.4%	67.8%	131.5%	120.0%	94.1%
Fixed telephone lines (millions)	1,197	506	691	13	33	549	74	249	262
Per 100 people	17.3%	40.9%	12.1%	1.6%	9.4%	14.0%	26.6%	40.3%	28.1%
Mobile broadband subscriptions (millions)	940	631	309	29	34	278	72	286	226
Per 100 people	13.6%	51.1%	5.4%	3.6%	9.7%	7.1%	25.9%	46.3%	24.2%
Fixed broadband subscriptions (millions)	555	304	251	1	8	223	24	148	145
per 100 people	8.0%	24.6%	4.4%	0.2%	2.3%	5.7%	8.7%	23.9%	15.5%
Source: International Telecommunication Union (October 2010)								via: mobiThinking	

So, can we do without our mobile phones? It is rather unambiguous that we want to have our mobile phones. For something that has a sometimes substantial cost associated with it, it is very clear that people everywhere can't do without their mobile phones.

5.2 Where do we go for content?

What about content? Do we go to CDs, DVDs, magazines, books and our local hard disks, that is, to local sources not dependent on an Internet connection? Or do we go on line? (As mentioned previously, one should always keep in mind that statistics should always be treated as suspect, not only because the same statistic from different sources often has different values, but also because of the ways that statistics can be presented to alter their perception [5] [6].)

Let's first look at what is happening with CD sales. According to data from Nielsen SoundScan, in 2007 CDs accounted for 90 per cent of album sales in the United States, with digital accounting for the other 10 per cent. Just two years later, that number had shifted to 79 per cent CDs and 20 per cent digital, with the remaining percentage point being made up of vinyl and other media. Billboard indicated that to 20 July 2010, about 44 million digital albums have been sold, compared with 40 million during the same time frame in 2009. While digital sales increased slightly, CD sales dropped from 147 million in 2009 to 114 million in 2010 for the same time period [9]. This graphic from SoundScan illustrates what is happening with respect to digital vs. media-based music sales [10].

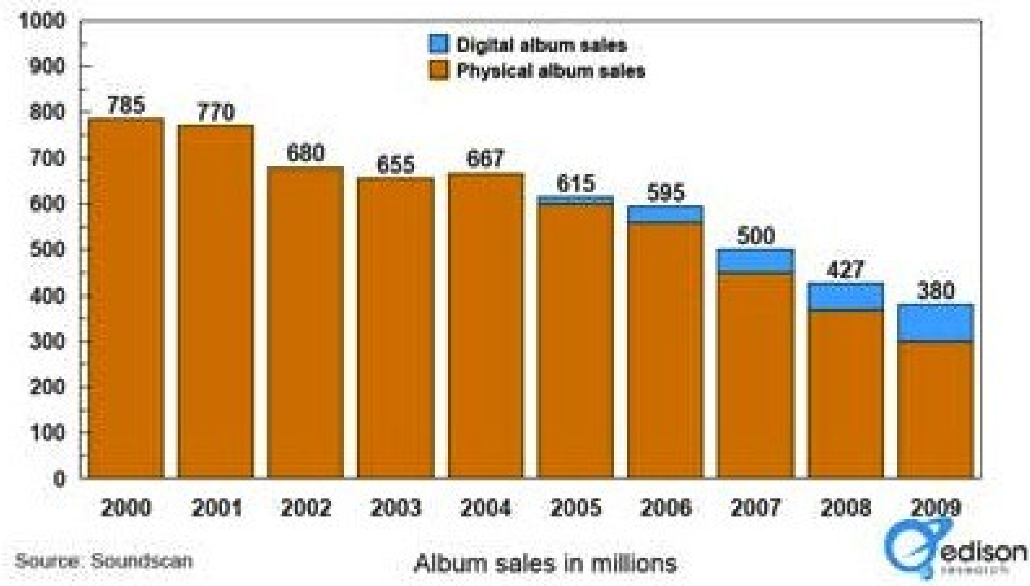

Figure 1 - Shifts in Music Album Sales in USA (SoundScan)

(It should be noted that SoundScan is not universally considered the most reliable resource for music industry data, and neither is the Recording Industry Association of America (RIAA), which claims that record sales have fallen by about 50% from 1999 through 2009 despite the shut down of various file-sharing sites which were accused of facilitating recording piracy. There are numerous pages on the World Wide Web that express and challenge various viewpoints on piracy of recordings over the Internet by various means, but that is outside the scope of this technical paper. What is relevant, however, is the fact that there are numerous legal sites for downloading recordings [11]. In addition, many artists, especially lesser know ones, enable and allow free downloads of their own material to gain exposure and enhance via their own web sites or via web sites such as Artist Direct [12].)

Music media sales have recovered somewhat but the increasing acceptability of digital downloads for music continues to grow. iTunes has been a great success for Apple as the available statistics indicate [13] but iTunes is far from the only source for purchasing and downloading digital music. CD sales in 2010 were down some twenty per cent but individual track downloads rose slightly while digital album downloads rose about thirteen per cent [14].

A factor that should not be overlooked in considering these statistics is that consumers no longer have the limited options of buying either the whole album or only the single(s) that the record companies decide to release. (For the reader of a certain age, this means either buying the "LP" or the "45.") With services such as iTunes, it is possible, for most albums, to buy almost any possible combination of its tracks. So, while album sales are showing some decline, especially in relation to the global economic situation, the sales of individual tracks are holding up well.

And what about DVDs (and Blu-Rays)? All indications are that the peak in sales was somewhere around 2007 and sales have been falling since. NetFlix is growing rapidly with in excess of 20 million subscribers in the United States [15]. All is not positive, as there have been some issues for NetFlix with respect to pricing, increases in content licensing costs and some missteps with respect to its by-post services. Nevertheless, it is clear that consumers are moving towards streaming services because of the breadth of choice, the immediate availability, no need to store physical media, etc.

And what about other media such as books and magazines? Electronic book readers (e-readers) such as Amazon's Kindle, Barnes & Noble's Nook, Chapters-Indigo's Kobo, Sony's Reader and many others have become popular in recent years, and continue to increase in popularity. Their advantages include long battery life (especially those with e-ink and related display technologies), portability, high storage capacity, nearly instantaneous availability (through on line stores and downloads) and no need to store ever-increasing quantities of physical books [16]. Many e-readers can also support subscriptions to newspapers and magazines. Improvements in performance, screen size, colour instead of monochrome displays, battery life and other capabilities such as internet browsing and the ability to run various applications (e.g., Apple's iPad 2) make physical media less and less attractive, especially for younger consumers who have grown up using personal computers and are entirely comfortable doing their reading on a screen. Statistics quoted in a USA Today article indicate a major publisher in the USA, Random House, is seeing some 20% of its revenues coming from electronic book sales in the first half of 2011 [17]. Electronic books are not limited to e-readers as many smart phones are also capable of displaying electronic books, but there are still issues with screen size and resolution, battery life and eyestrain from the backlit screens, although all thee are declining. Apple's iPhone 4S, for example, offers a very high resolution screen in a relatively small form factor: a 3.5-inch / 8.9 cm (diagonal) widescreen display with 960 by 640 pixel resolution at 326 pixels per inch / 128 pixels per centimetre [18].

So do we go on line as our first choice for content? Perhaps not yet for everyone, but we are on our way. Clearly, younger people will lead this for reasons already mentioned, and while older people may prefer the feel of books, newspapers and magazines in their hands, they, too, will become more and more accustomed to electronic media due to its advantages.

5.3 How are we managing our contact lists?

What about contact lists? Anyone with more than one device capable of a creating and using a contact list in some form will have found it to be a problem trying to maintain and synchronize these by application, device, and individual situation. There are increasing numbers of services that enable synchronization across multiple devices. Apple's MobileMe [19] is one example and it is transitioning to iCloud [20]. Google's sync service is another [21].

An important aspect of these services is that they use "push" to update other devices when something is updated on one, e.g., adding or updating a calendar entry or a contact on one device results in the addition or update being pushed to all the other devices. This is one example of an area where additional data is being transferred from and to smart phones on a mobile operator's network, often without the non-technically inclined subscriber being more than peripherally aware that something is going on in the background.

5.4 Looking to the future

It is clear that the trend is to more and more content on line, and more and more content is sought first on line. Among young people in developed economies, it can safely be said that are connected all the time, everywhere, and that the only place they go for content is on line. And while it is true that there is a declining proportion with age that "live on line," the numbers are growing. In so-called developing economies, what is apparent is a phase lag due to relatively lower income levels, offset by a significant advantage: they do not need to go through the various legacy systems and steps but can take advantage of the latest technologies and the lessons learned in the so-called developed economies, plus they will enjoy the benefits of the economies of scale which will deliver high capability at low cost.

What about everything being connected?

- Everyone and everything is connected all the time, everywhere
- The only place people go for content is on-line

Internet users sitting at their desks with their personal computers have become well acquainted with the capabilities of the Internet as an electronic means of access to a global library. As they have become more and more accustomed to the capabilities of search engines, they naturally want to have access to these things wherever they are. In other words, users do not like to be "disconnected" or "off line." Now, when a person has a device in his or her pocket or purse with which it is possible to quickly and easily access the Internet, and the resources that he or she wants to access have become well known, or are easily found using search engines, then we enter into a situation where being connected all the time, everywhere, is the norm expected by such users.

Not mentioned so far is social networking. There are numerous chat rooms where it is possible to use instant messaging to interact with groups of people of similar interests. Instant messaging, as the name implies, also allows a user to send a brief text message to another user in near real time, and to get a response in near real time. The "near real time" aspect means that senders expect that the people they send their messages to will receive them and will respond in "near real time." If this is to happen, then the users must be connected all the time, everywhere. Add multimedia capabilities to what originated as a text only medium, and the desire and desirability of being connected all the time, everywhere, grows. Add to this equation social networking sites such as Facebook [22] and LinkedIn [23] among others, blogging, tweeting, etc., and the desire to be connected all the time, everywhere just keeps growing.

While everyone does not yet only go online for content, it is certainly possible for a person today, if equipped only with a smart phone, to not need access to any physical medium for content: everything he or she wants can be accessed on line. With a smart phone and a tablet computer, even the smart phone's limitations in screen size are no longer an issue. And the cost of tablet computers is plummeting: India is looking at USD35.00 for a basic tablet computer [24]. China and India have achieved levels of penetration of mobile telecommunications that would have been considered impossible not very long ago: 873.6 million in India and 939.5 million in China as of September 2011 as reported in December 2011 [25].

Back to the question about the validity of the predictions: it should be clear that they are valid for the more developed economies, and also for a rapidly increasing proportion of the population of the world as a whole. Advances in technology coupled with economies of scale are making it possible to be on line and gain access to content even for populations that could not have enjoyed this just a short time ago.

6 Setting the Context II – Humans Not Involved

Having reviewed the human activities driving the rapidly increasing data traffic, it is now time to consider the traffic that is not directly attributable to human activities. In this technical paper, we say "not directly attributable" because all machine-to-machine communications can be traced back to human activities in setting them up. What is different here is that these communications take place nominally without further human intervention.

This section considers the increasing usage of automation to handle repetitive and well-defined tasks. These are further described in the section on use cases but several are considered here as the basis for this section.

6.1 Using Telecommunications to Free Humans from Repetitive Tasks

There are a number of key differences between people and machines:

- Machines are good at routine and well-defined tasks that require a constant level of attention; people get bored by repetition and stop paying attention, make mistakes, and miss inputs.
- People are very good at tasks that require intelligence and adaptability; machines cannot cope with events outside their programming.
- Machines can react to inputs very quickly; human responses are slower.

As technology has evolved, there have been enormous changes in capabilities and costs:

- More computing power, memory and communication capabilities make it possible for machines to take over tasks presently done by, but not well suited to human beings.
- Declining costs make it practical for machines to take over tasks not well suited to expensive human beings.
- Increasing capabilities and lower costs together open new opportunities for revenue generating services not previously economical to do.

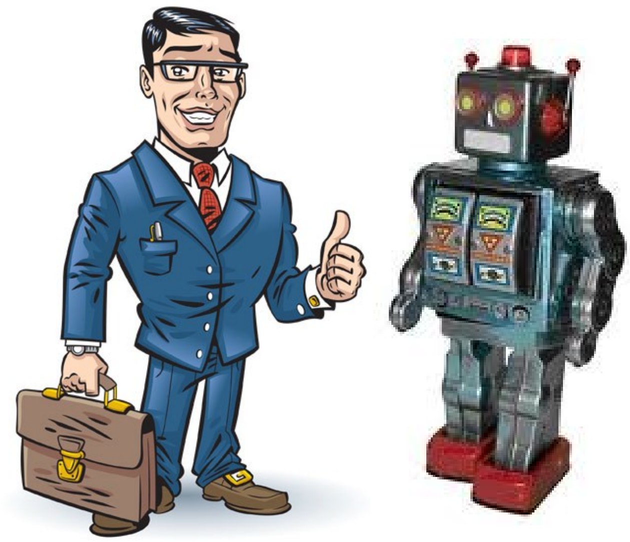

Figure 2 - Humans and Machines - Suited to Different Types of Tasks

Several reasons that humans look to automation are to reduce costs and to reduce errors. Sending a person to every residence and business periodically to read a utility meter is expensive. The person expects to be compensated for his or her time and effort sufficiently to support a reasonable standard of living. The task is highly repetitive and humans are poor at repetitive tasks, therefore errors will be made and need to be corrected. In many cases, there are multiple utilities, (e.g., electricity, gas and water. Each utility has its own meter, and its own meter reading process and staff. Reading intervals can be quite long, often monthly but even longer in some situations such as remote locations. Besides the labour intensive nature of the meter reading process, there is no capability for early detection of abnormal usage, no simple way to take an out of sequence meter reading, e.g., for a change of occupancy, and no easy way for the typical consumer to monitor usage. The obvious answer to these problems is to enable the meters to communicate with some form of service centre. This communication can be at any desired periodicity, and multiple centres need not be used if the various utilities can agree on a cooperative arrangement or use a third party proving this as a general service.

With such a centralized system receiving appropriately frequent readings, it becomes possible to provide consumers real time, or close to real time data on their usage and the costs they are incurring. For example, the service centre could provide a smart phone application current information to indicate both usage and costs for multiple utilities at any desired interval.

If the meters use the data capabilities of the mobile networks to send their readings to the service centres, and the consumers use their smart phones to access that information, then there are two sources of data traffic for the networks, recognizing that the second does involve humans, while the first does not. Consider a city of more or less one million inhabitants in a developed country or a developing country that has made significant progress towards developed status. Depending on various factors, it can be expected that there will be on the order of one half million electricity meters for all the residences and businesses in that city. If all these meters send current readings at, say, one-quarter hour intervals, then the mobile network must handle some forty-eight million data readings per day. And that is before any consumers try to access their current data. This represents a not insignificant load on the mobile network's data capabilities. The load becomes a further problem if every meter tries to send its data at precisely quarter hour intervals. Network operators will immediately recognize that having a large number of devices try to access the network simultaneously at regular intervals is not desirable, indeed is the antithesis of the stochastic nature of voice telephony traffic that is used to engineer voice networks. And this problem is multiples by three if we add gas and water meters into the mix.

In many places, vending machines are used to dispense products such as hot and cold beverages and various food items to consumers. Similar problems to those for meter reading apply in respect of regular visits to check stock and retrieve cash payments. Further, such visits may be too early (little consumed, little cash on hand) or too late (running out of stack, cash box full) so a natural desire is to be able to service a vending machine at an appropriate time considering the actual sales and state of the cash box. This would greatly enhance the efficiency of service calls to the vending machines. To accomplish this, these machines need to communicate to a service centre that can dispatch personnel as needed. The amount of data to be transmitted can be presumed to be rather more than what is needed for meter readings, but is also likely to be more amendable to being sent during low traffic periods on the network.

Another example is monitoring of infrastructure. A bridge may be fitted with sensors of various types to measure vibration, load, and other factors. Information from these sensors may be needed in real time in some situations (e.g., an extra heavy load is being sent across the bridge) but non-real time in other situations (general monitoring of the bridge.) In this scenario, one can envisage traffic that is collected and stored locally and then sent during low traffic periods. Alternatively, the various sensors could send data periodically and engender problems similar to those mentioned above for meter reading. Sometimes, the sensors may be set up such that no data traffic is generated unless what is being measured exceeds a threshold value. Now suppose there is an earthquake. This may cause many or all of the sensors to exceed their thresholds and then all will try to send their data at the same time. This is clearly an undesirable situation from a network operator's point of view, especially as human initiated traffic is likely to suddenly increase in such a situation, yet it can be very important in terms of infrastructure safety if the measurements indicate imminent failure of the bridge and closing it to traffic could prevent loss of life.

6.2 An Initial Look at Issues in M2M Communications

Some of the issues in machine-to-machine communications have already been alluded to. There are many more. Consider gas and water meters. In order for these to function safely, it is highly desirable that they not be connected to the electricity supply for the obvious reasons in case of malfunction (fire, electrocution.) This means that they must be battery powered, hence significant effort must be applied to conserving that power since frequent battery replacement would quickly negate the value of automating the meter reading process. Therefore, strategies need to be developed for how some meters are managed such that extended battery life is not only possible but also routinely achieved. Another issue, not so much for electricity meters, but very much the case for gas and water meters, is the need to do out-of-sequence readings for change of residence and similar reasons. An always-on electricity meter can be read easily, but a gas meter that provides a reading at much longer intervals represents a different problem entirely. One approach is to have the meter briefly listed for a "trigger" at certain intervals, but the duration and frequency of the listening periods can greatly affect battery life.

Consider environmental sensors for atmospheric conditions such as used for weather forecasting. Add sensors to measure air and water pollution. Add sensors for measuring agricultural conditions such as soil temperature and moisture. Add sensors such as for earthquake monitoring, an especially important consideration in earthquake prone regions of the world such as Japan, Turkey, the west coast of North America to name just a few.

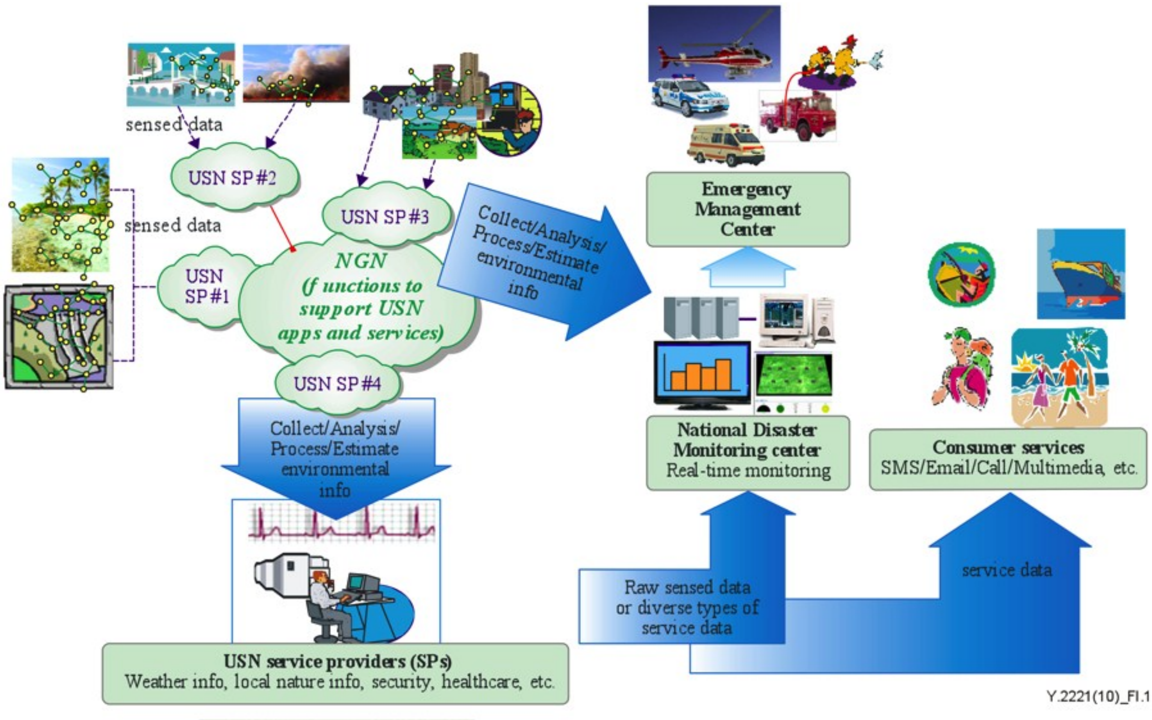

Figure 3 - Variety of Machine-to-Machine Communications

Now consider monitoring of road traffic. In many instances, users are charged tolls for usage of highways, etc. In a number of cities, users are charged tolls for merely driving into the city centre during certain periods. The life of the driver is made easier and traffic moves much better if sensors can collect information on which vehicles pass by certain points and send that information back to a processing centre.

A transportation company wants to monitor its vehicles. These may be equipped with transponders or with communication devices that use positioning systems (GPS, Galileo) and report their status at regular intervals. The goods being carried can be outfitted similarly, and report their status at intervals as well.

Residence or business security systems can monitor for temperature, the presence of water, intrusion, etc. While most of the time, there will be no problems detected, there is still the need to ensure that the system is able to contact the appropriate response centre. That traffic can be relatively infrequent and with very little content, but large numbers of such systems will add significant cumulative traffic load. When a problem is detected, the amount of traffic and the characteristics of that traffic can change dramatically. A system that send a few bytes very few minutes as a "heart beat" where some minor irregularity in receipt may be quite tolerable, can shift to needing real time video streaming when a problem is detected.

All of the above serves to support the assertion that the number of devices wishing to communicate can be expected to be two orders of magnitude greater than the number of human devices. And the traffic these devices can generate varies widely.

7 Impact of Data on Mobile Networks

Public Land Mobile Networks (PLMNs) were originally designed and deployed for circuit-switched voice services. As such, they were initially modelled after Public Switched Telephone Networks (PSTNs) that used analogue circuit-switched technology. These first generation systems soon gave way to second-generation systems using TDD, FDD and CDMA technologies to increase capacity and performance. PSTNs evolved from analogue to digital. PLMNs did as well. PSTNs evolved from circuit-switched to packet-switched. PLMNs did as well as they evolved to third and fourth generation systems. The details of this evolution are outside the scope of this technical paper but, of course, may be explored by using search engines on the Internet to find articles on these topics.

7.1 Data as Voice and Voice as Data

While PSTNs and PLMNs both started with voice as the primary, if not their only offering, there was soon demand for data to be transferred from origin to destination as well. For both the PSTN and PLMN, this started out by making the data appear to the networks as if it were voice through the use of modems. This worked well for low data rate applications such as facsimile and basic email, but it soon became apparent that there was demand for more data.

Figure 4 - Data on a Voice Network

As data technology improved and the demand for more data grew, there was a fundamental change: voice was no longer the focus but data was. This meant that networks were now being designed to carry data first, and that voice had to be transformed to look like data through the use of modems. But now the modems are used for the voice communications instead of the data communications.

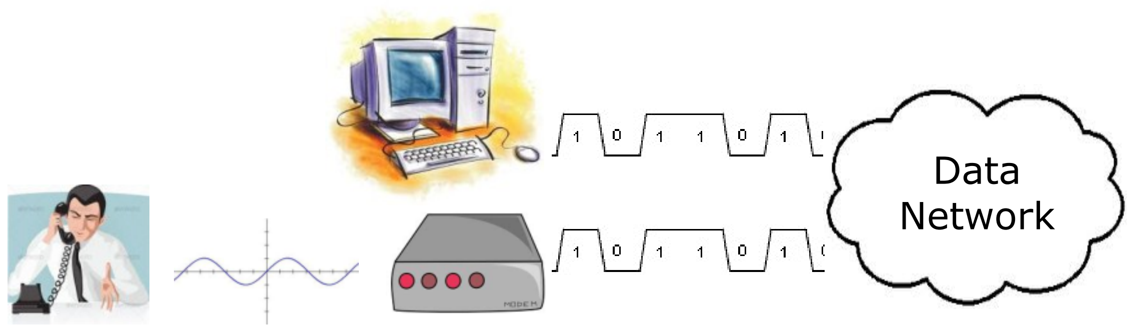

Figure 5 - Voice on a Data Network

Over time, the ability of both PSTNs and PLMNs to carry data has grown considerably. In the early 1990s, the capabilities were limited to modems that could use the narrow bandwidth of the radio channels and thus provided 9.6Kbps. Gradually, the technology improved until we are seeing early deployments of LTE delivering 12 Mbps and more, with forecasts to the 150 Mbps range [26].

7.2 Recent Forecasts

In a recent document submitted in a liaison statement from ATIS[1] to 3GPP[2], some interesting and relevant graphs are provided [27].

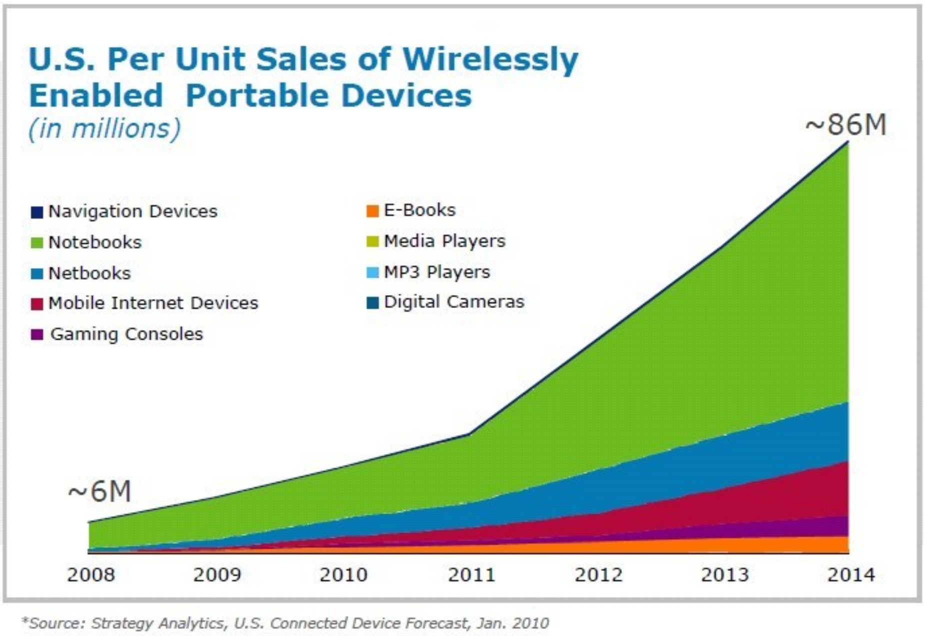

Figure 6 - Forecast of Sales of Wireless Enables Devices

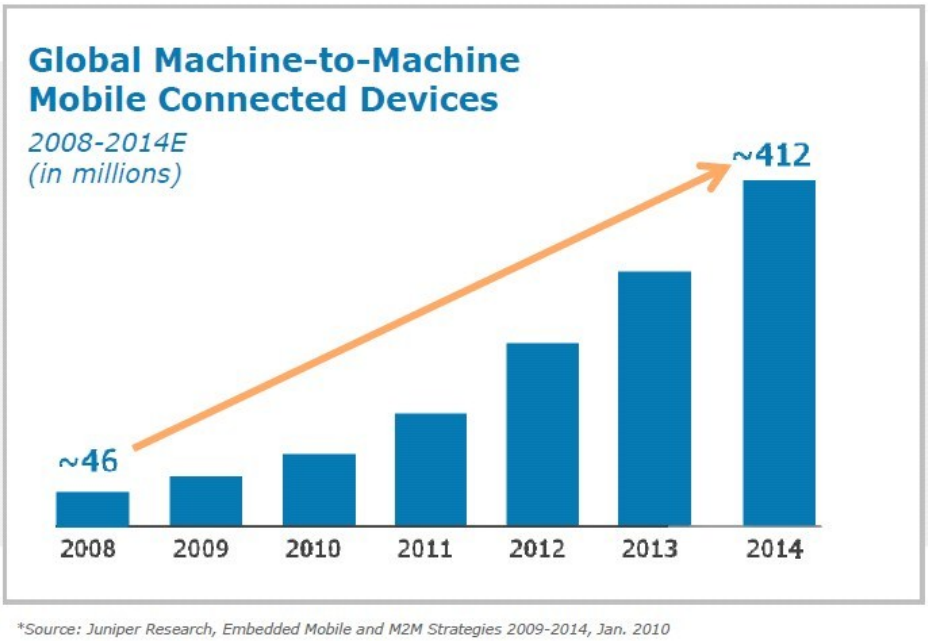

Figure 7 - Forecast of M2M Connected Devices

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[1] ATIS: Alliance for Telecommunications Industry Solutions: www.atis.org

[2] 3GPP: 3rd generation Partnership Project: www.3gpp.org

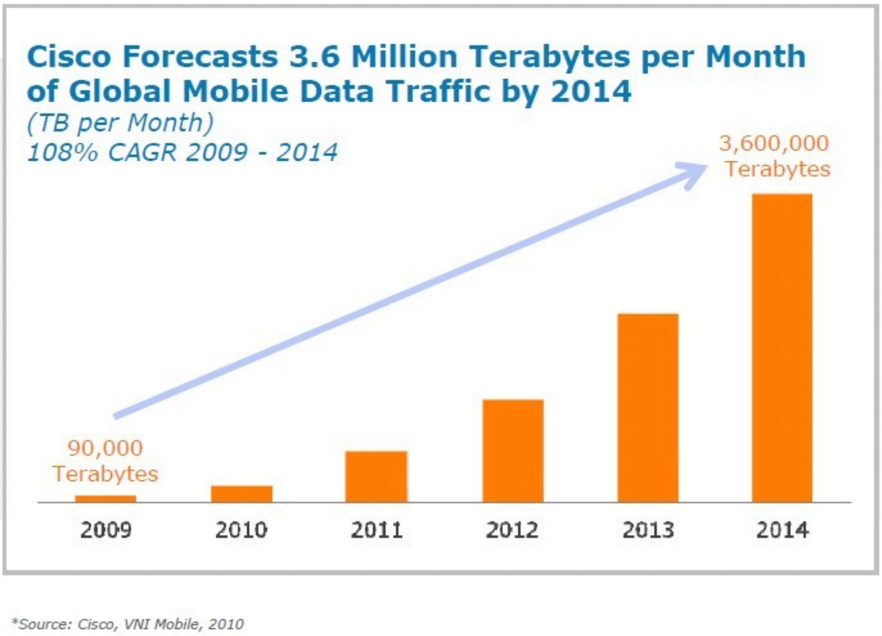

Figure 8 - Forecast of Mobile Data Traffic

The above figures and diagrams give insight into general increases anticipated for M2M communications. It is worth looking at forecasts for a developed country that has done a study on this area to see what the scale may be. Japan's Ministry of Internal Affairs and Communications[3] published a discussion paper on M2M and potential impacts on the numbering system to cope with the increased number of cellular phones [28]. The range of applications considered is illustrated in Figure 9 - Japan: Extract of Discussion Paper on Impact of M2M that includes translation from Japanese to English. The forecast of the number of M2M devices in the Japanese market is shown in Figure 10 - Forecast M2M Market Size in Japan. These figures are extracted from [28] which includes additional web links but most of the information is in the Japanese language. Nevertheless, it serves to indicate anticipated penetration of M2M devices in a developed market serving about 126.5 million people [29]: some twenty-five devices per person. Forecasting is at best a highly inexact activity[4] but it is clear from multiple sources that one to two orders of magnitude of additional communicating devices should be expected.

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3 www.soumu.go.jp/english/index.html

4 Niels Bohr, Danish physicist: "Prediction is very difficult, especially if it's about the future.

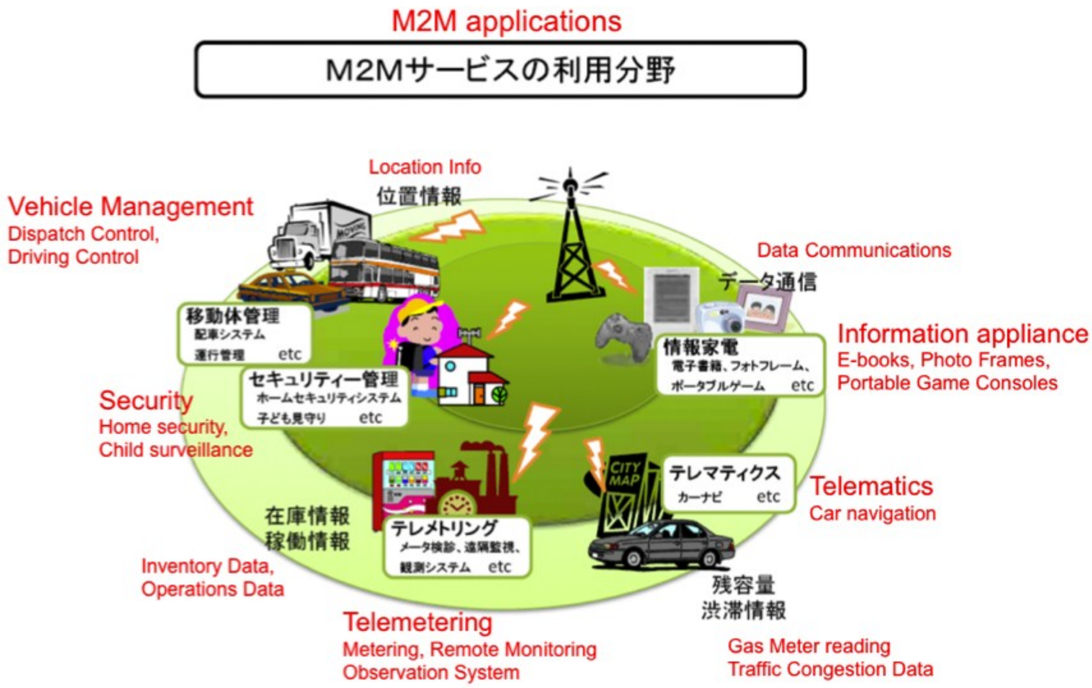

Figure 9 - Japan: Extract of Discussion Paper on Impact of M2M

M2M Market Size in Japan

想定されるM2Mサービスの需要母体

	No.	もの (Market segment)	推計数 (Estimated Number)	
E-books	1	電子書籍端末	690万	6.9 M
Digital Photo Frames	2	ディジタルフォトフレーム	300万	3 M
Digital Signage	3	屋内外電子公告	200万	2 M
Cars	4	自動車（二輪車、貨物・特殊用途含む）	7800万	78 M
Bicycles	5	自転車	7900万	79 M
Home Appliances	6	IT・白物家電	6億	600 M
PCs	7	パソコン	5200万	52 M
Vending Machines	8	自動販売機	520万	5.2 M
Electricity/Gas/Water Meters	9	電気・ガス・水道メーター	2億4000万	240 M
Street light	10	街路灯	4700万	47 M
Environmental Sensors	11	自然環境調査用センサ（地震、CO2濃度等）	3800万	38 M
Sensor for Monitoring River Flow Rates	12	河川流量監視センサ	100万	1 M
Agriculture Sensors	13	農業用センサ	18億5100万	1,851 M
Others	14	その他	1億6690万	166.9 M
Total		計	31億7000万	3,170 M

Figure 10 - Forecast M2M Market Size in Japan

Considering the number of M2M devices that are expected to connect to the network, and that a common requirement is that all such devices be uniquely identifiable, a key issue is the potential for exhausting numbering plans. To this end, studies are underway or complete in ITU-T Study

Group 2 under Question 1/2 [30], 3GPP [31] and 3GPP2 [32]. Solutions are available and convergence on an industry-wide solution may be anticipated in due course.

7.3 Revenues

Voice once provided all the revenue, including the revenue from data that was made to look like voice. What is being experienced now is relatively limited growth of voice but enormous growth of data traffic: the number of human users is increasing but there is a finite number of humans on the planet; the number of machines humans are creating and that need to communicate to provide their functions is not bounded in the same way.

Rapid growth in data usage on mobile networks does mean growth in data revenues. For network operators, it is essential that the revenues for data carried reflect the costs of carrying that data. Operators are charging for data usage but the situation is uneven. For example, roaming charges for smart phone mobile data usage can be exorbitant while home network data usage charges may be limited or even provided at a "flat rate," i.e., unlimited usage for a fixed price.

For many M2M scenarios, there will be pressure from customers to have very low prices for the data being handled. In many cases, especially where there is considerable time tolerance, that is not a problem. In other cases, timeliness may be more important than price.

One of the major costs for a mobile operator is spectrum licencing. While this varies in different regulatory environments, one of hey key issues is the availability of spectrum. The high demand for mobile communications coupled with the scarcity of spectrum results in high value for a given piece of spectrum and hence high price. M2M communications can provide additional revenue for an operator if they can be constrained to periods of otherwise low usage, resulting in additional revenue for resources that would otherwise be idle at those times. But not all M2M communications can be handled in that way, hence there is the problem of increasing demand on a finite resource. Managing this demand with suitable tariffs is an important factor in the nature and cost of the communication resources that can be provided to M2M applications.

A brief but very interesting summary of voice vs. data revenues in several major markets is provided by [33]. A graph attributed to Vodafone shows the enormous increase in the ratio of data traffic to voice (Figure 11) while also showing that voice traffic, while continuing to grow, does so at a much slower rate.

It indicates the differences that tariffs can create in the behaviour of users, while also recognizing that there are cultural factors at play. Japan was forecast to have data revenues exceed voice revenues in late 2010.

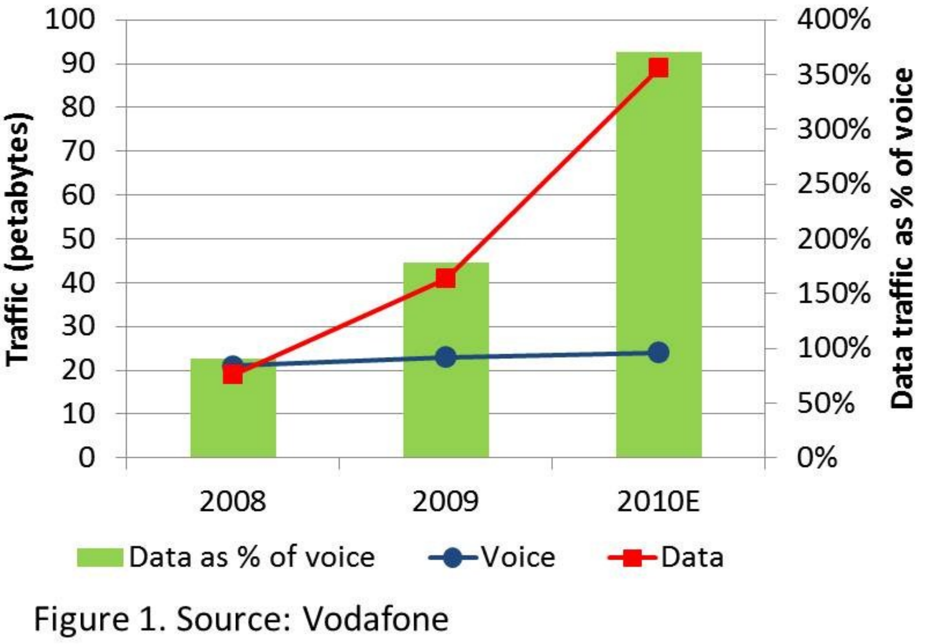

Figure 11 - Change in Voice vs. Data Traffic Pattern [33]

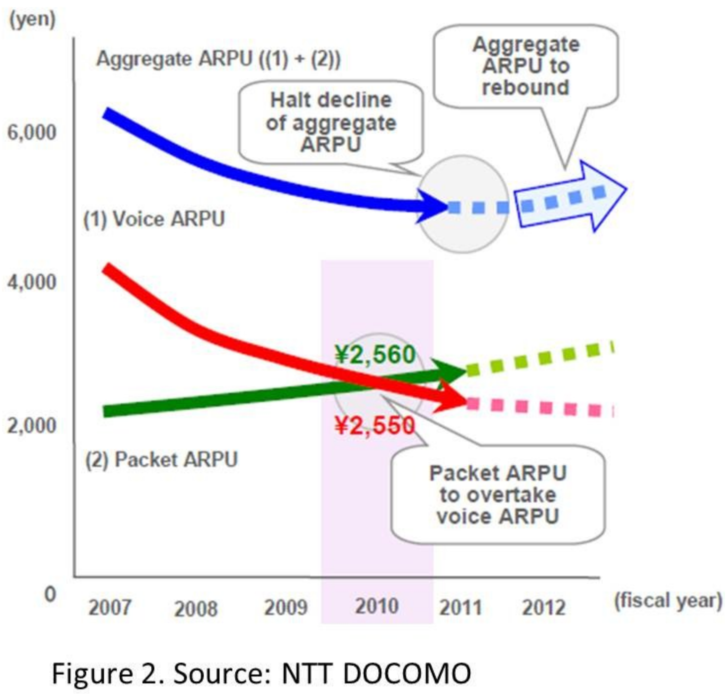

Figure 12 - Data Revenue Overtakes Voice Revenue [33]

The amount of data traffic Japan is seeing is increasing in all the three categories of character-based (email, web browsing, etc.), still images (pictures, noon-streaming) and video (real time streaming.) This is illustrated in Figure 13.

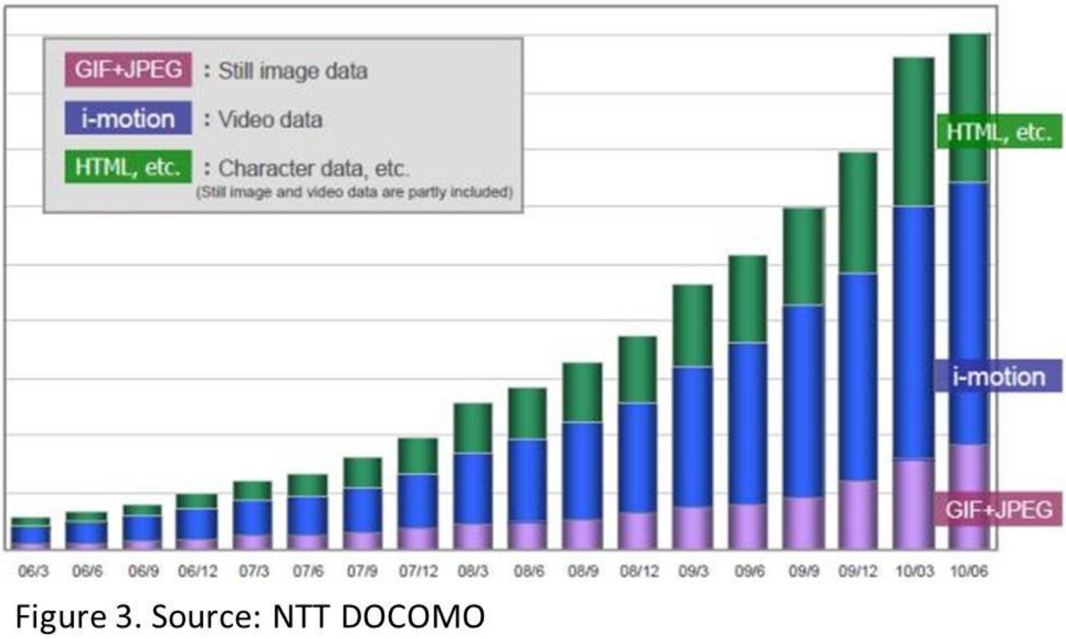

Figure 13 - Types of Data [33]

In the UL, Ofcom has looked at the proportions of usage of mobile phones by activity and by age group. The interesting result is shown in Figure 14. While Europe and the USA are not yet at the point that Japan has reached (data revenues exceed voice revenues), both markets are clearly on that path.

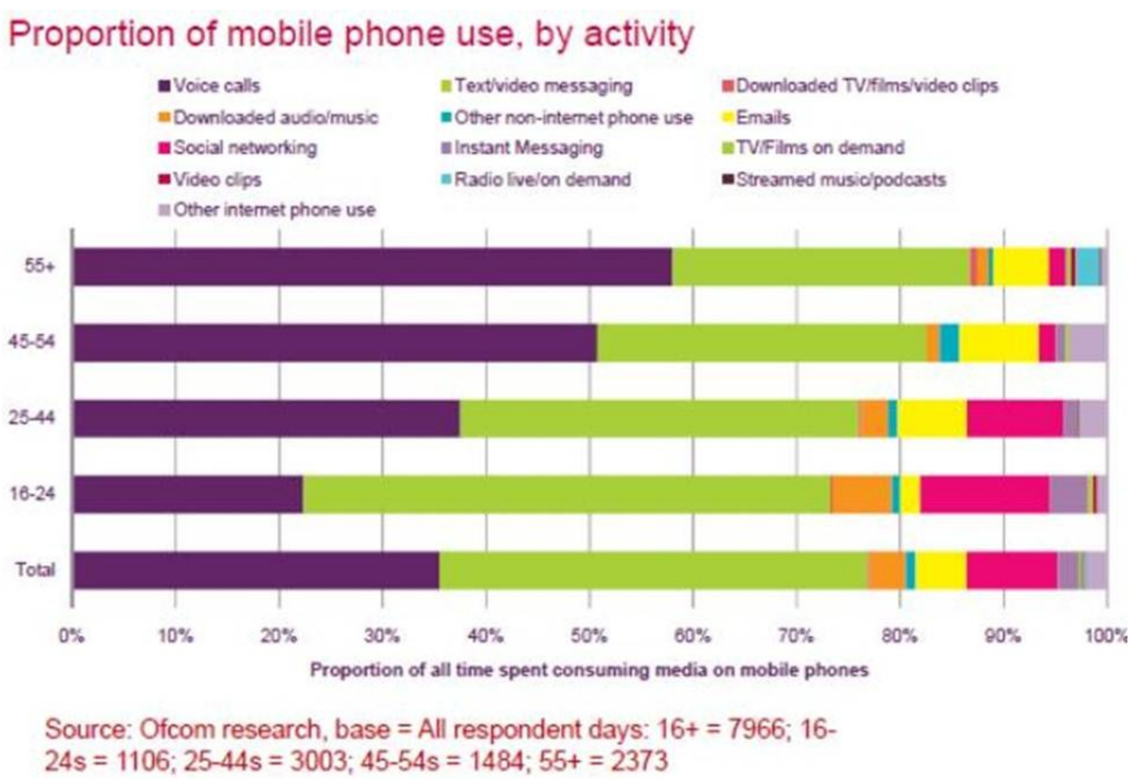

Figure 4. Source: Ofcom

Figure 14 - Proportion of Mobile Phone Use by Activity [33]

Of interest is the last sentence of this article: “In fact the very distinction between data and voice is bound to disappear or lose most of its significance as voice increasingly gets treated as a data application.”

In Japan, the problems associated with the rapidly increasing intense data usage are causing operators to look for various ways to offload their mobile networks. KDDI has extensive WiMAX service offering called UQ [34] and has recently partnered with Ruckus to provide one hundred thousand Wi-Fi access points for data usage [35]. Despite all these efforts, KDDI is very concerned about the volume of data traffic it will have to handle. KDDI forecasts that its LTE network will reach its limits in 2014 [36]. To cope with all of this data traffic, KDDI is using a “3M” strategy, consisting of Multi-Use, Multi-Network and Multi-Device [37].

8 M2M Use Cases

Many use cases can be identified. The following table is extracted from [38] and provides a summary of areas where M2M communications may be applied along with some examples. A number of these examples will be explored in more depth.

Table 2 – M2M Use Cases

Security	Alarm systems Backup for landline Access control Car/driver security
Tracking & Tracing	Fleet Management Order Management Pay as you drive Asset Tracking Navigation Traffic information Road tolling Traffic optimisation/steering
Payment	Point of sales Vending machines Loyalty concepts Gaming machines
Health	Monitoring vital signs Supporting the aged or handicapped Web Access Telemedicine points Remote diagnostics
Remote Maintenance/Control	PLCs Sensors Lighting Pumps Valves Elevator control Vending machine control Vehicle diagnostics
Metering	Power Gas Water Heating Grid control Industrial metering

8.1 Use Case: Pay as You Drive

There are a number of different situations within this use case. One is simple toll collection for use of highways and bridges. Another is monitoring entry and exit to a defined geographic area. Yet another is detailed tracking to monitor usage for such purposes as insurance premiums.

On major highways and structures such as bridges, tolls are collected from those who use them to recover the cost of building and maintaining them in preference to imposing these costs on the general population through taxation or other means. However, collecting tolls is labour intensive and slows traffic considerably, especially during peak periods.

In congested urban areas, a fee for entry to the area is imposed to discourage private vehicle usage and encourage public transit usage to reduce congestion, and encourage greater use of public transit infrastructure making it more cost effective (more revenue from riders through higher occupancies.) Examples of cities where this is done are London [39] and Stockholm [40]. Governments may also look on the fees as an additional revenue source for either maintaining the roadways, etc., within the designated area, or for general revenue.

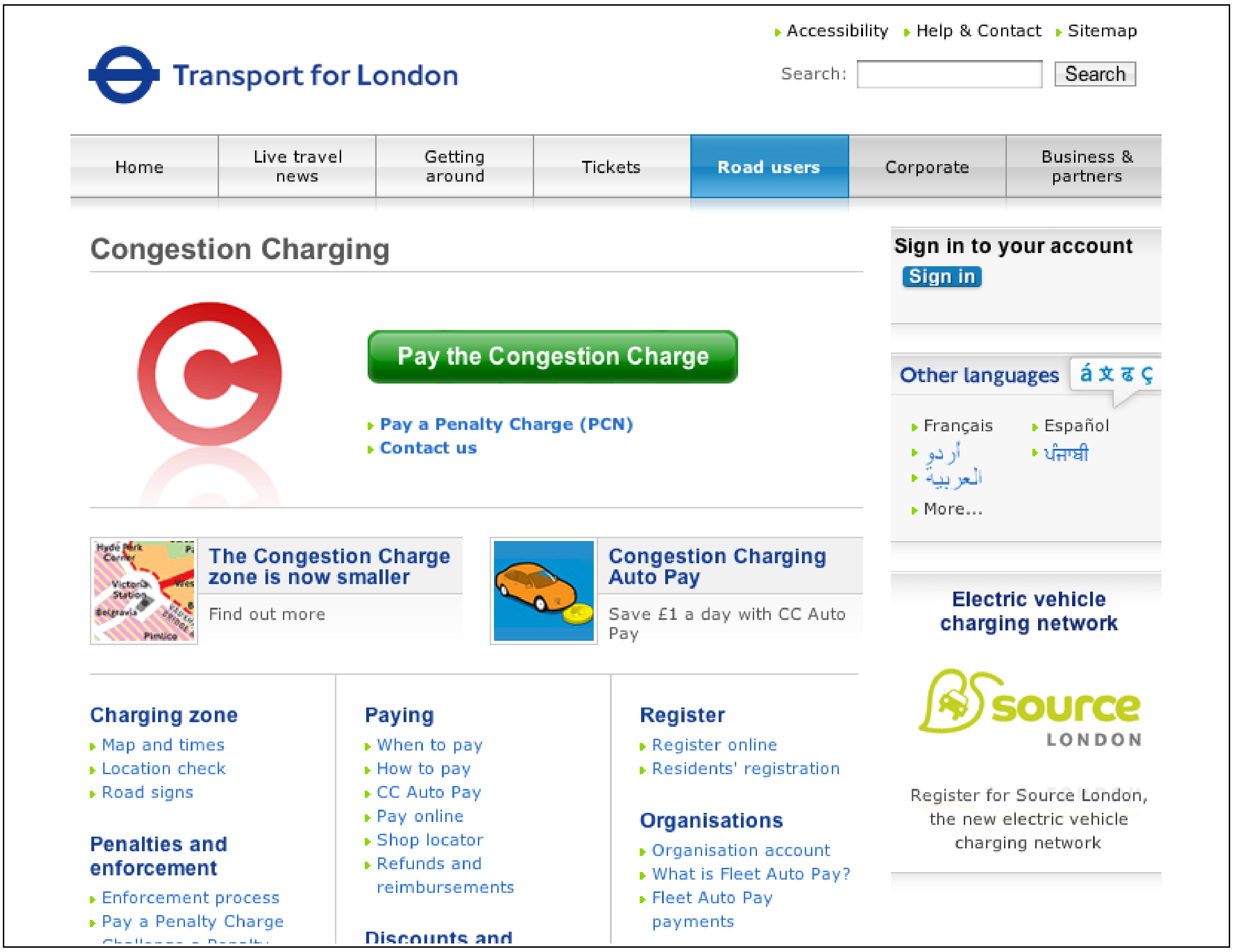

Figure 15 - Part of "Transport for London" Web Page on Congestion Charging

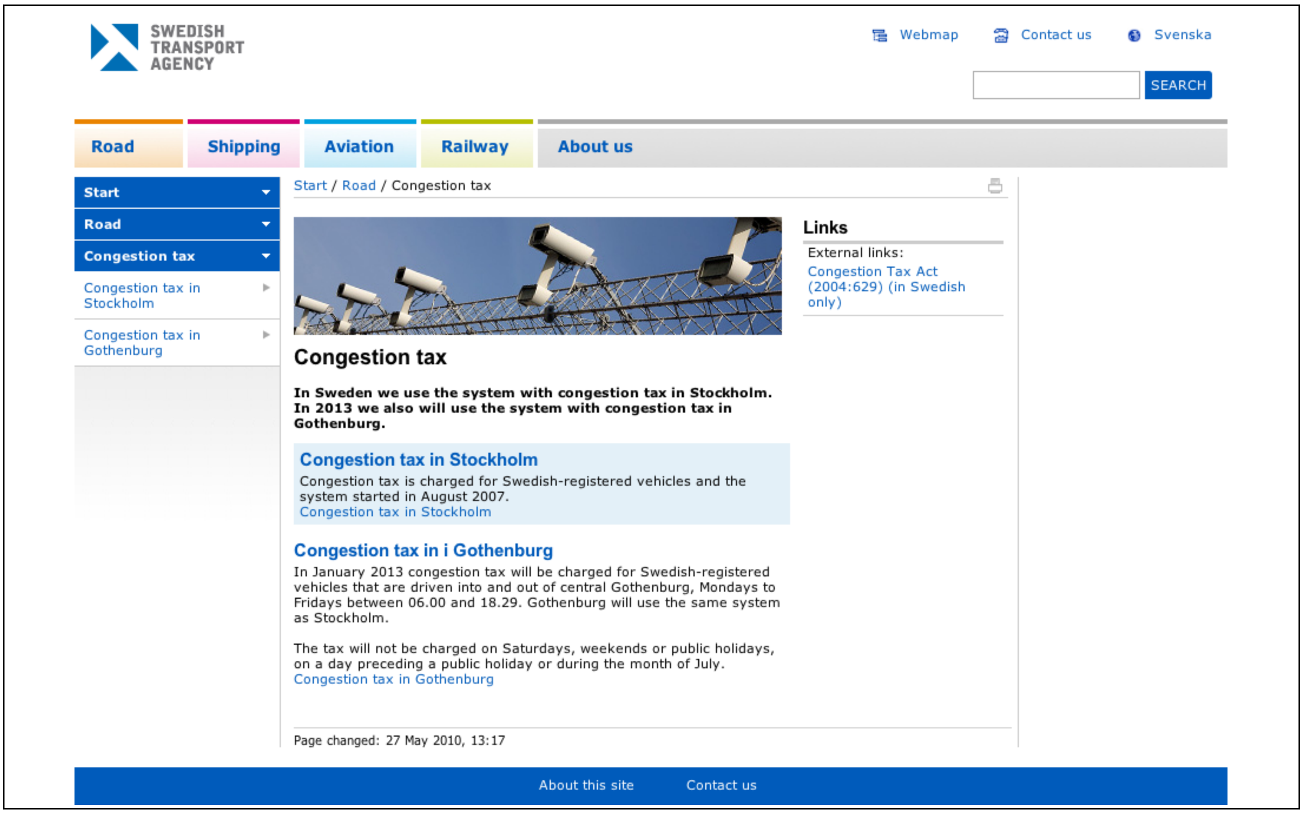

Figure 16 – "Swedish Transport Authority" Web Page on their Congestion Tax

Insurance premiums for vehicles are generally set based on relatively broad usage categories. These may include the type of vehicle (compact, utility, luxury, sports, etc.), where the user lives (some areas are prone to theft or vandalism), commuting distance (the greater the distance, the greater the likelihood of collisions), the age and experience level of the driver (younger and less experienced drivers are more likely to be involved in collisions) and the driving record (number and seriousness of speeding and other moving violations.) Insurance premiums could instead be based on actual usage if that usage can be tracked.

Usage data for toll roads, bridges, and urban areas to be used as the basis for billing can be collected through transponders at checkpoints, but this still requires alternate means for infrequent users. Photographing licence plates can be used but licence plates may be obscured by dirt or ice and snow, and the billing is then against the owner of the vehicle rather than the user, although this may not be a significant concern.

Another method of collecting tolls is to install and man tollbooths but this is labour intensive. Tollbooths can also be automated but this presents some issues such as how to deal with motorists who do not have the correct change or an acceptable credit card. Whether manned or not, toll booths are also subject to damage from inept drivers, and are subject to damage and theft by criminals.

There are several ways to get around these problems. One is to provide a transponder in vehicles so that they can be tracked as they pass through checkpoints. The resulting data is used to invoice the vehicle owner. This option is well suited for frequent users but not well suited to infrequent users. It is widely used to reduce the number of tollbooths and to speed the flow of traffic through toll plazas.

Another option is to photograph the licence plate on each vehicle as it passes a checkpoint. This does not work well if the licence plate is obscured by dirt or snow and ice. It also requires suitably equipped checkpoints for collecting the images for subsequent processing and invoice generation.

If location and time information on the location of a vehicle can be recorded (e.g., with a GPS system), then all of tolls, access fees and insurance premium calculations can be derived based on the resulting data. However, in many areas, there are significant privacy concerns on the collection and usage of such data.

The requirements for “Pay as You Drive” tracking systems will vary by the nature of the services to be provided, both to the authorities collecting the tolls and to the individual drivers. The volume of data from each sensor point is very likely to be large enough that it would not make sense to characterize the amount as “small data” other than in very specific circumstances. (“Small Data” is characterized in 3GPP as up to 1K (1024) octets [41].) For authorities collecting tolls, it may be sufficient to simply collect data and download it *en bloc* once per day from each sensor point. The timing of the download can be negotiated with the operating company to ensure it is done at a low network utilization time.

On the other hand, drivers may wish to know their accumulated charges as they go. This requires a different approach where the user equipment installed in the vehicle or carried by the driver must be provided with an updated accumulated charge in a form suitable for displaying to the driver. Without looking at issues such as driver distraction, it me be in presumed that the driver will want to know in near real time the amount of the latest increment, and likely the total for the current day. The user equipment can also be expected to store data for some period of time so that the user or driver can review it at a suitable time that will not interfere with safe operation of the vehicle. In this case, the requirement will be for a small amount of data that likely falls within the 3GPP definition mentioned in the preceding paragraph, and will be needed in near real time. Consequently, it can be expected that the load on the operator’s network will be highest when the traffic is busiest, that is, when the maximum number of vehicle sis passing by the sensor. Unfortunately, such busy traffic periods may correlate closely with other usage peaks.

8.2 Use Case: Security

Security is an interesting use case because of the range of possible communications that may be needed. These include:

- Status checking: the monitoring system can be periodically verified as active and functioning
- Alarm report: an alarm condition has occurred and needs to be reported for action
- Visitor verification: a visitor needs to be viewed and interacted with on order to be validated
- Multiple communication means for redundancy

Alarm system status checks need to be done on a periodic basis to confirm that communication between a central monitoring system and the individual (residential or business) system is not only possible but also available and capable. Whether this is originated from the central or remote system is not important: it is essentially a two-way query response that assures both entities that communication is possible when necessary. The frequency of this “heartbeat” needs to be set based on a variety of application related factors, but the key one for the mobile operator is the frequency that is decided on. If status checks are frequent and there is a very large number of systems being checked, the overhead of this information transfer can become quite significant.

When an alarm condition occurs, it is to be expected that close to real time reporting of the detected event will occur so that whatever action is appropriate can be initiated. A long delay in response to intrusion, fire, water leakage, excess carbon monoxide or naturel gas detection, etc., will not be appropriate as anything that impedes rapid response may lead to loss of life or property.

An alarm system may be connected to the monitoring location by multiple means to enhance its reliability, especially should there be an attempt to compromise it by cutting the terrestrial communications as part of an intrusion. The most likely arrangement will be some form of terrestrial facility and a backup wireless facility. The loss of the terrestrial facility will not isolate the alarm system. The use of the terrestrial facility will allow offloading of the wireless facility where spectrum capacity may be at a premium, particularly in dense urban environments, but also in rural environments where capacity is likely to be limited due to costs. A related aspect is backup power for the system so that it remains functional should normal ("mains") power be lost. It is clear that a mobile network UE would serve his purpose well.

A feature that some systems may wish to offer is real time video. This can be for one or more purposes such as checking on visitors at the entrance without opening the door and remotely checking on parts of the premises as available via camera installations that are part of the alarm system. Some systems offer the ability to send vide on demand from cameras to a remote user. The remote user could access the system using a dedicated device, a general-purpose personal computer via, e.g., a web interface, or a UE that is a smart phone. (Smart phones are discussed further later in this technical paper.) Figure 17 provides a generic example.

Home Security Apps for Smart Phones
These apps enable on-the-go users to be aware of and control their residential or business office security and climate control systems from anywhere. The apps are fully integrated with the security company's alarm systems to offer remote security system monitoring, receive alarms instantly, see video from security cameras (real time or stored), and check sensor status. The sensors can be door and window status, motion detectors, plus temperature, moisture, carbon monoxide, etc., detectors. A history of events can also be accessed. The apps can also be integrated with climate control systems to enable monitoring and control of heating, ventilation and air conditioning systems.

Figure 17 - Example Smart Phone Applications for Home Security

What is plain from this description is that the operator's network should anticipate carrying a large number of relatively low priority, brief interactions for verifying functionality, plus infrequent but very high priority alarm indications, plus widely fluctuating (in time and duration) real time video and audio streaming situations. These characteristics can make this use case a difficult one to manage.

For access systems, particularly for a large facility with many access points, it is desirable to control access centrally. Therefore, it is desirable to have wireless communication for the access points to a central server so that any attempt to gain access at any access point can be verified. This applies not only to general access, but also to control of zoned access, where only certain individuals may be permitted entry but others not.

The requirements for access systems may be for many access verifications in a relatively short period of time (e.g., a shift change) to a slightly less demanding situation (e.g., start of day or end of day) to on demand where access may be requested at any time. The nature of the access control can therefore be expected to have to support significant peaks in communication at certain time of the day, plus on going and relatively lower level needs outside the peak periods. In all cases, though, real time response will be expected as individuals legitimately seeking access will not want to wait more than a very few seconds for their access to be verified.

8.3 Use Case: Tracing and Tracking

When assets are moved from place to place, it is often desirable to have a current view of their whereabouts and status. (The value of the asset will influence how closely tracking is desired, but many assets of nominal individual value can still be valuable in terms of the reputation of the business involved: only a few lost or misdirected items can substantially damage that reputation.) This applies not only to the more obvious things such as trucks (tractors and trailers) or rail cars or ships or aircraft in a fleet, but also to the less obvious things such as the individual items of cargo they carry. The items tracked could be as large as a shipping container or as small as individual envelopes in a courier service. A business that involves the transport and delivery of goods needs to track not only the good but also the delivery vehicles so that it can both verify the status (location and situation such as temperature for goods that are temperature sensitive – may need to be kept frozen or must not be frozen or must not exceed a certain temperature or other environmental condition) of the goods being handled, and be able to make good decisions for the effective use of its vehicles.

Figure 18 - Truck Fleet

In some cases, the tracking needs to be continuous and in real time or near real time, e.g., for local delivery. In other cases, less frequent monitoring is sufficient, e.g., long haul delivery where the fact that an item is loaded and the estimated time of arrival are known. In the former case, frequent monitoring of location and status may be important while, in the latter case, infrequent monitoring is sufficient. When a vehicle is transporting many items of cargo, it is should not be necessary to communicate with each of them frequently, but rather it is important to communicate with items that are being loaded or off-loaded at “stations.”

Passive monitoring can be done with GPS Data Loggers and mapping software providing results such as in Figure 19 [42] but these require access to the unit to retrieve the data for after event review.

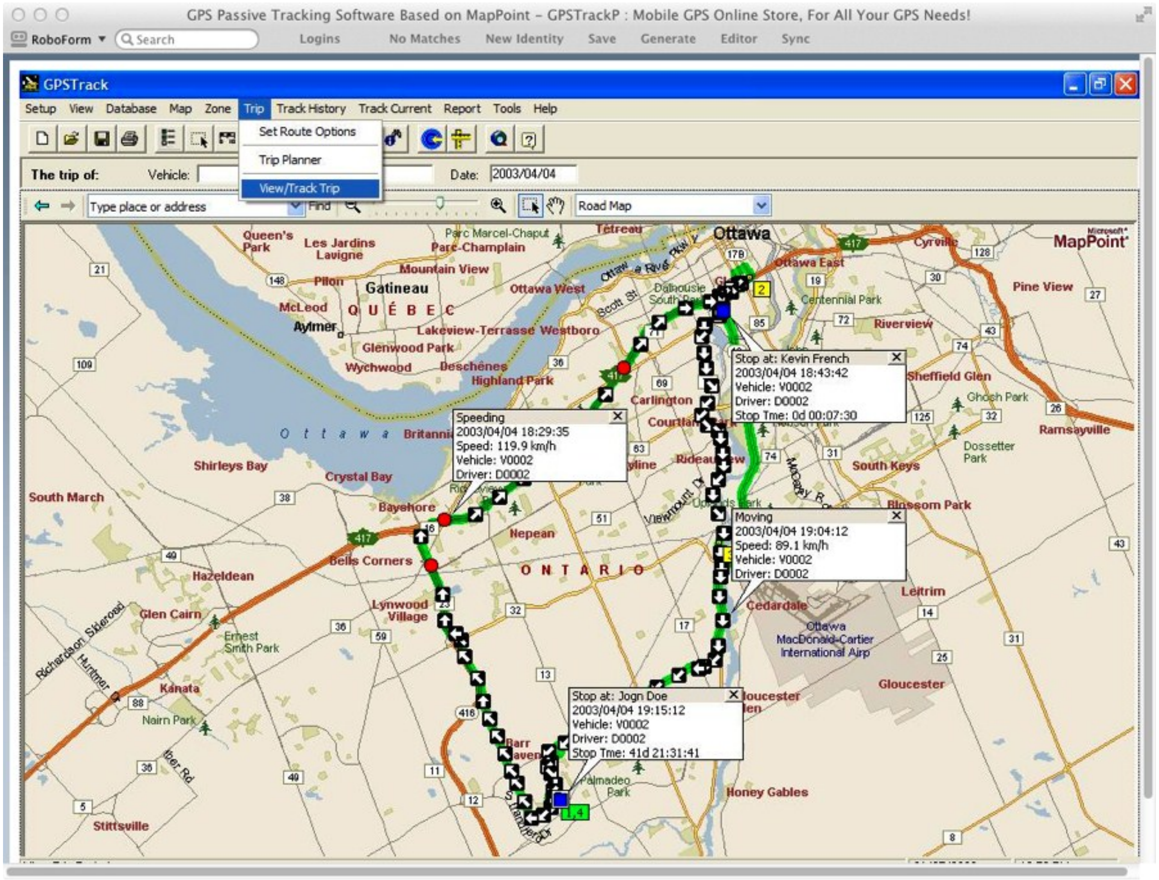

Figure 19 - Display of Results of Passive GPS Monitoring

The requirements from the network operator's point of view can vary widely. If the collected data that has been collected at selected points is time tolerant, and can be sent at a later time to a central point, the resulting data traffic will normally be quite manageable. Tracking of items being stored in a warehouse will not be time sensitive while the items are being stored, however much of the data for tracking items being transported will be relatively time sensitive, and in some cases very much so. Hence, some of the data will be non-time sensitive "bulk" data, and other will be time sensitive "small data."

8.4 Use Case: Payment and Inventory

Point of sale terminals may be used to handle debit or credit card payments. Early forms used a dial up circuit-switched connection from a fixed terminal and were therefore somewhat slow and cumbersome as the terminal was in a fixed location (the staff or customer or both had to go to the terminal to process the payment) and more time was required to establish the circuit-switched connection than was required to execute the query response. With packet switching, a session could be maintained as long as needed and would be ready for use essentially instantaneously. By adding wireless functionality, it becomes possible to move the point of sale terminal to wherever it is needed, such as directly to a table where patrons at a restaurant are seated so that the inconvenience of doing the transaction at a central cash register area is avoided.

Figure 20 - Point of Sale Terminal

Payments can take several forms. In a coffee shop, a small payment might be made for a relatively simple purchase using a smart phone or a credit card equipped with a transponder, such as MasterCard PayPass credit card [43] or NTT DoCoMo's Osaifu-Ketai or mobile phones with wallet functions [44], also offered by KDDI, SoftBank and Willcom in Japan. The purpose is to speed up the payment process so that individual customers are not kept waiting while their payments are being processed, and to enable more customers to be handled by the same resources. It is particularly appropriate for small transactions where profits depend on speedy service.

Figure 21 – MasterCard PayPass and Visa payWave Enabled Credit Cards and Terminals

Figure 22 - NTT DoCoMo: Convenience of "Osaifu-Keitai"

For vending machines, this is at the vending machine's location, and thus it become possible to pay at a vending machine with not only the local currency but also with debit and credit cards, and with devices that can be set up to provide the applicable information so that the point of sale recognizes them as valid forms of payment, e.g., mobile phones acting as wallets as described in the preceding paragraph.

It is worth recalling that, in the early days of credit cards, merchants had a "floor" transaction level where the credit card would be honoured by the banking institution issuing the card for transaction below a certain level, but that the card had to be checked against a "black list" for transactions above that amount. If the card was on the black list and was not checked, the merchant would be liable for the charge. This was very cumbersome and slow at the point of sale, plus it required frequent printing and distribution of the black lists to all merchants. This laborious, error-prone and rapidly out-of-date process was soon abandoned as point of sale terminals were installed and upgraded to quickly verify the debit or credit card with the relevant institution or a central clearing house at the time of use.

Once a vending machine is capable of handing a debit or credit card transaction including verification of the card at the time of sale as a condition to dispensing the product, it can also provide inventory updates. Or the reverse may be the case: once a vending machine is able to report its inventory status, it can also be equipped to handle debit and credit card transactions. In both scenarios, the situation is the same: real time payment verifications and relatively time insensitive inventory updates.

These capabilities represent increased convenience for users (they don't need to have exact change or sufficient local currency to be able to use the vending machine.) They also represent increased value for vending machine operators: the machines need to be visited and restocked only when necessary, and the profile of products stocked can be adjusted to reflect actual consumption patterns. When applicable, the vending machines can also have their cash boxes emptied and their change supplies refreshed so that they are always ready to sell their products. This is good for consumers: they have access to what they want when they want; and good for vending machine operators: stock item selection and stock levels are optimized to what people actually purchase.

Once again, the requirements range from "small data" transactions in real time to larger file transfers that are not particularly time sensitive. The same comments as for previously mentioned similar situations apply.

8.5 Use Case: Health Care

There are a number of situations where untethered health monitoring is highly desirable. When a person is very ill and must be confined to a hospital bed for treatment and recovery, tethered systems can provide the needed means for measuring and collecting relevant data. However, in medicine it is well known that the earlier a patient becomes mobile, the more rapid and complete the recovery. Therefore, while monitoring of vital signs may continue to be very important, being able to do so while enabling the patient to move around is also important, although the areas where the patient may move to may be constrained.

Figure 23 is from ITU-T Recommendation Y.2221 [45] and shows a Ubiquitous Sensor Network (USN) health care scenario.

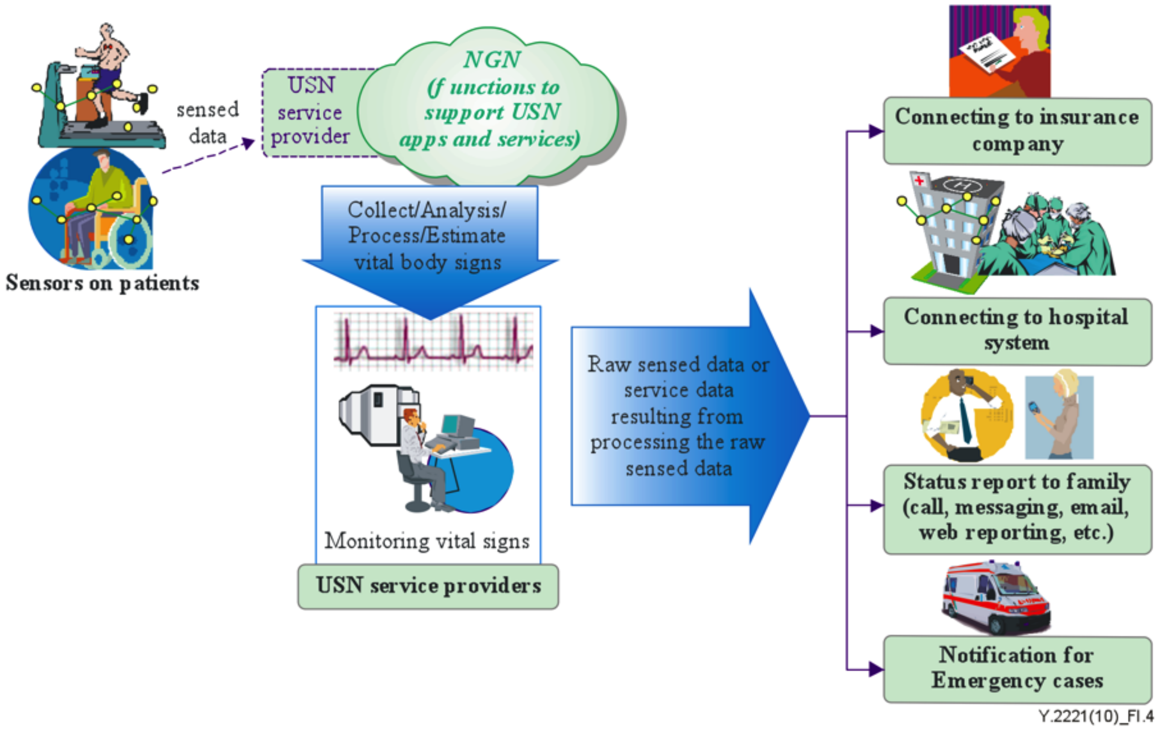

Figure 23 - USN Health Care Service (ITU-T Rec. Y.2221)

For elderly or handicapped persons, monitoring may be needed due to existing or accumulating medical issues, but without wishing to unduly restrict the person's freedom to move around.

In some instances, the monitoring of vital signs may observe a crisis requiring rapid intervention, such as when heart rhythm changes indicate a heart attack. In such cases, the requirement is that communication from the sensor to the appropriate responders must be rapid and highly reliable as a life may be at stake. In other instances, a trend line may be sought and the data may be accumulated by the sensors and periodically sent to a central point for analysis. One such example might be blood sugar monitoring for a diabetic or potentially diabetic patient. The situation is not immediately life threatening but the correct diagnosis depends on having adequate data on which to base it.

Especially for elderly but also for handicapped persons, another monitoring function may be related to falls. An accelerometer in a sensing device can detect when the person falls and could either initiate communication with a response centre immediately, or alert the person and allow for a short period of time in which the person can indicate whether help is needed, or if no response I provided, then communicate with a response centre.

The requirements in this category include real time, reliable communications for emergency situations (heart attack, etc.) or slightly less urgent situations (assistance after falling, etc.) One of the issues that arise in these cases is that mobile service may not be available everywhere. In some buildings, there is enough steel in the structure to reduce signal strength to unusable levels when near the core of the building. This may also occur in elevators, underground parking facilities, etc.

It may also occur in coverage "dead zones" in urban environments, as well as no coverage in rural or remote environments. Some of these aspects can be addressed through suitable restrictions on the person's movements, but the concern to the mobile network operator is the potential for liability in case the emergency communication could not be completed. Other causes beyond the operator's control may affect the reliability of communications, such as loss of power, damage or destruction by weather or earthquake or other natural disaster, vandalism, etc. If life-dependent services are to be provided, the operator, the person involved, and the response centres all need to be well informed of the risks.

The requirements related to accumulated data it be sent for analysis are similar to other use cases.

8.6 Use Case: Remote Maintenance and Control

It is desirable in many situations to be able to monitor systems and controls remotely. One obvious reason is reduction in personnel costs. Other reasons include hostile environments, infrequent need for intervention, and convenience.

Two quite similar maintenance use cases examples can be described as characterizing this group. One is computer-controlled machinery. These devices may have parts that wear from usage, such as cutting blades and bits, etc. The typical life of such a part is likely well known but its usage may be quite variable so the accumulated usage needs to be monitored so that a replacement can be provided and installed when needed. Similarly, other parts may need periodic maintenance such as lubrication, filter replacement etc. The other use case is transportation engines, covering the range from automobiles to trucks, trains, ships and aircraft, which require periodic lubrication (oil changes), filter replacements, etc. The frequency of replacement will depend not only on the characteristics of the engine, but also the characteristics of its use: "hard" usage will require more frequent service. Another maintenance item is software updates to deal with flaws, or to add features. These may be infrequent, but could be significant in size and scope.

The requirements for remote maintenance are for moderate amounts of data that is not particularly time sensitive, hence does not present a big problem for the network operator. Software updates can present a problem, especially if they are large and frequent, or if they are large and need to be done to many devices at the same or nearly the same time.

Control functions can be fairly simple, such as controlling lighting and heating at a residence or business. Turning lighting on or off may or may not be time sensitive, depending on whether it is done in preparation for someone's arrival (e.g., wanting the lights on when one arrives home) or needing to turn them on remotely because someone has arrived and has no means to turn on lighting. Adjusting heating is unlikely to be time sensitive since heating or cooling has a much longer time constant than turning lighting on or off.

Remote control of remote equipment, or equipment located in a hostile environment, is needed in many cases. Pipelines have pumps and valves at various locations to control the flow of material. Control (as well as monitoring) of these from a central location is desirable. In some environments, the presence of high temperatures, toxic fumes or radioactivity may make the environment hostile to humans. Remote control is clearly desirable in these situations.

The requirements for these situations will generally fall into the real time and highly reliable categories, but "small data" will be sufficient for most of the interactions.

8.7 Use Case: Metering

Meter reading is a labour intensive activity that is not well suited to the way human beings function. Therefore, automated systems to read meters for electricity, natural gas, water in residential and commercial situations, and possibly other utilities in industrial situations, are desirable. This has been discussed earlier in this technical paper.

There are several considerations that apply to determining the requirements in this area. When the PLMN is to be used for communication between a meter and a server, the availability of electrical power can substantially influence the requirements.

Electricity meters have ready access to power to support their communications functions so there is not an issue here: their ability to remain attached and on line is not influenced by the availability of electric power.

On the other hand, natural gas and water meters will typically not be connected to a source of electricity but will be battery powered. Since a meter is expected to be installed and undisturbed for an extended period of time (on the order of ten years), for natural gas and water meters battery life due to consumption becomes a very important factor. Therefore, it is expected that they will spend a high proportion of time in a "deep sleep" mode where they are not connected to the network and are neither able to send or receive data.

When meters are to be read at long intervals, such as once every two months, then the meter can stay asleep for a long period of time, wake up and send its reading, and go back to sleep. This works well except when a change of residence requires an out of sequence reading. Alternate methods are needed to deal with such cases. One is to use human meter readers for thee cases. Another is to have the meter "wake up" for a brief period at a suitable interval so that it can be triggered to send an out of normal scheduled reading at a specified time. This approach implies that the meter wakes up long enough to listen for a triggering message, and is then able to store information from that message so that it wakes up to send a reading at the indicted date and time before resuming its normal schedule. This will require careful coordination between the utility's servers and the settings on the meters on when they "wake up" and listen for a trigger.

For some utilities, especially electricity, it will be desirable to read the meter more frequently, especially if the utility wants to offer a service where its customer can get close to real time information consumption data so that adjustments can be made to move demand to either turn them off or to move them to lower cost time periods. In such situations, readings will need to be provided frequently. Providing an electricity meter reading every fifteen minutes represents almost six thousand times the frequency of a gas or water meter that sends a reading once every two months, plus it represents a demand for readings that is constant rather than one that can be positioned at times of the day when traffic levels are otherwise low.

Figure 24 – Electricity. Gas and Water Meters

Looking beyond simple meter reading, a "smart home" will include multiple devices that need to be managed. Part of the impetus for "smart metering" of electricity is the management of loads so that generating facilities can be better utilized through shifting loads from otherwise high usage periods to lower usage periods in order to achieve a more uniform daily demand. So-called "smart grids" are part of this since they are expected to draw power from many small facilities such as solar panels on a building, and also have to manage substantial loads such as recharging the batteries of an electrically powered vehicle. With the anticipated proliferation of such devices and the associated control complexity, a significant amount of application data must be exchanged to mange it all. This represents a challenge for network operators due to the increased data volumes they will be asked to carry.

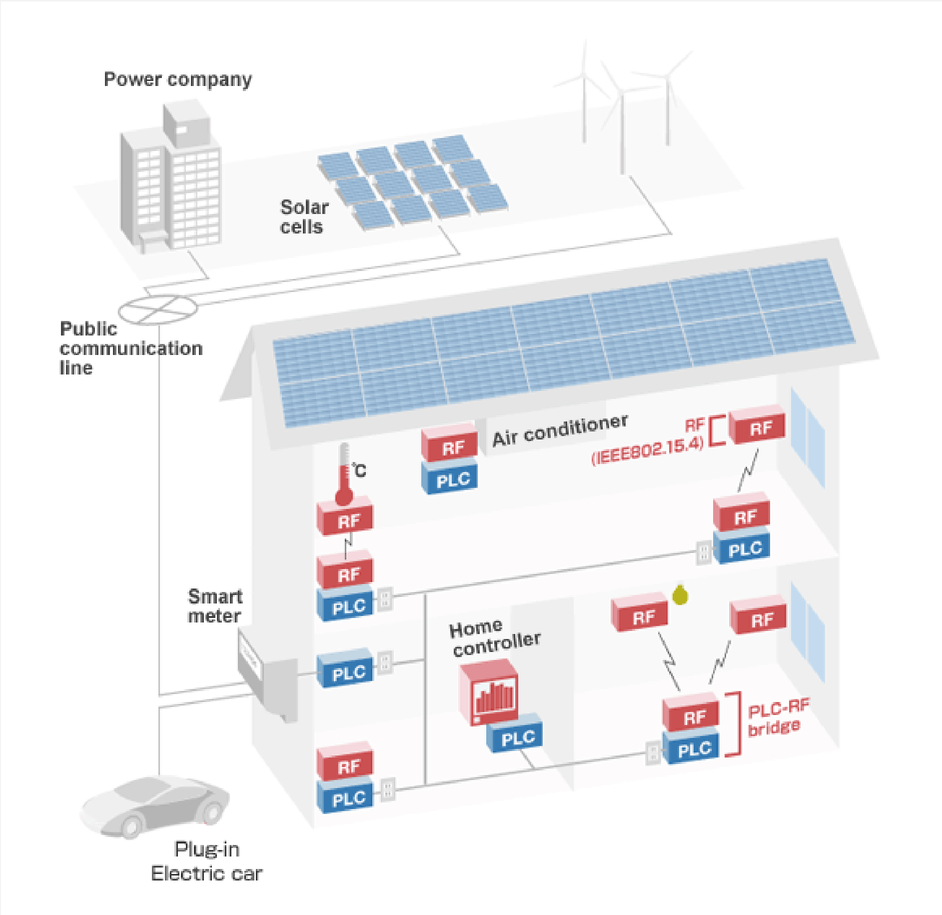

Figure 25 - Example of a Home with Multiple Controlled Devices

8.8 Anticipated Evolution of M2M

Currently, there are many M2M systems in place. The products and applications in this "first wave" tend to be characterized by being proprietary in many ways although they use the existing mobile networks to support their communication needs. As proprietary solutions, they tend to be more expensive than a standard solution would be (due to economies of scale not realized in proprietary scenarios) as well as tying the end user (customer) into a specific manufacturer's products, which could lead to limitations in product evolution as well as maintenance should the manufacturer decide to discontinue the product.

Regulatory interest in applying M2M technologies to various large-scale problems is leading to a second wave with standardized solutions. The actual pace of progress may be less than regulators hope for but that is part of the nature of progress in standards development: it is rarely as fast as one would like due to the many questions that arise, vested interests that want to be protected, and the natural creativity of the engineers who do the standardization and who try to find optimal solutions to many different sometimes competing aspects.

As these regulated requirements are met, it is anticipated that the result will be a suite of capabilities that are highly attractive to the markets of the first wave who will be looking for better solutions, and to many potential users who have waited until the needed standards have been developed and are in place. It is anticipated that a "critical mass" will be reached which will then drive the M2M market based on its inherent value and capabilities.

The above is illustrated in Figure 26 – Anticipated Three Phases of the M2M Market.

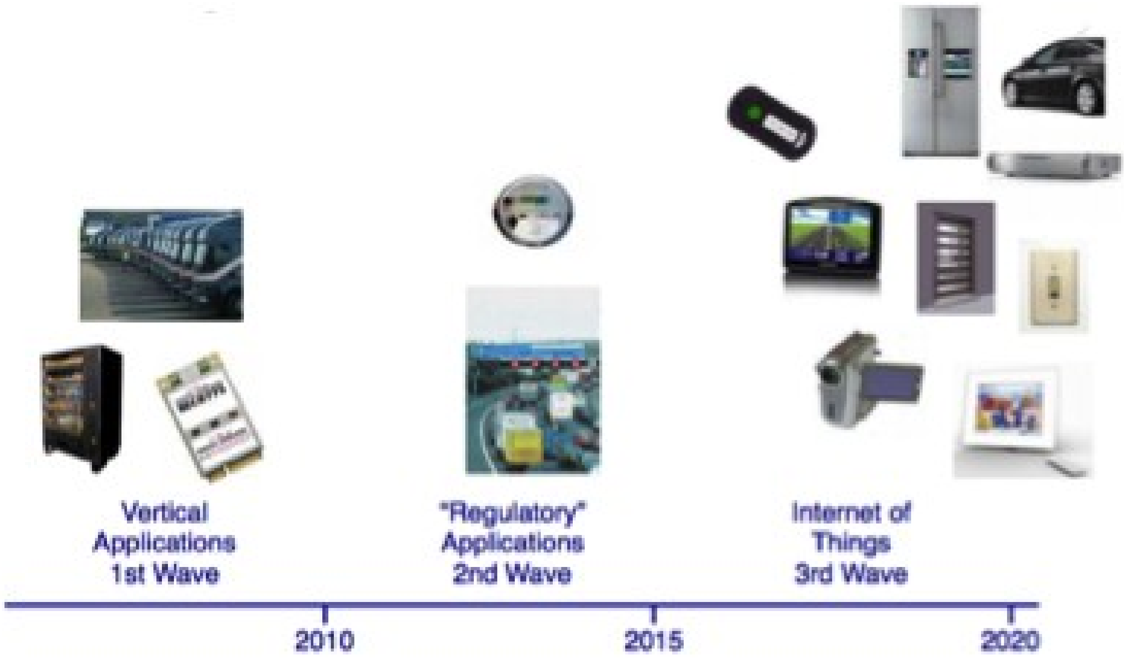

Figure 26 – Anticipated Three Phases of the M2M Market

8.9 Summary

In reviewing the various use cases, it becomes clear that there is considerable variation in requirements. This is effectively captured and summarized in Figure 27 [46], created by the Rapporteur for M2M in 3GPP SA1. While it is possible to argue about the specifics of the various applications and their associated characteristics, the message from this figure is that there is significant diversity in these characteristics.

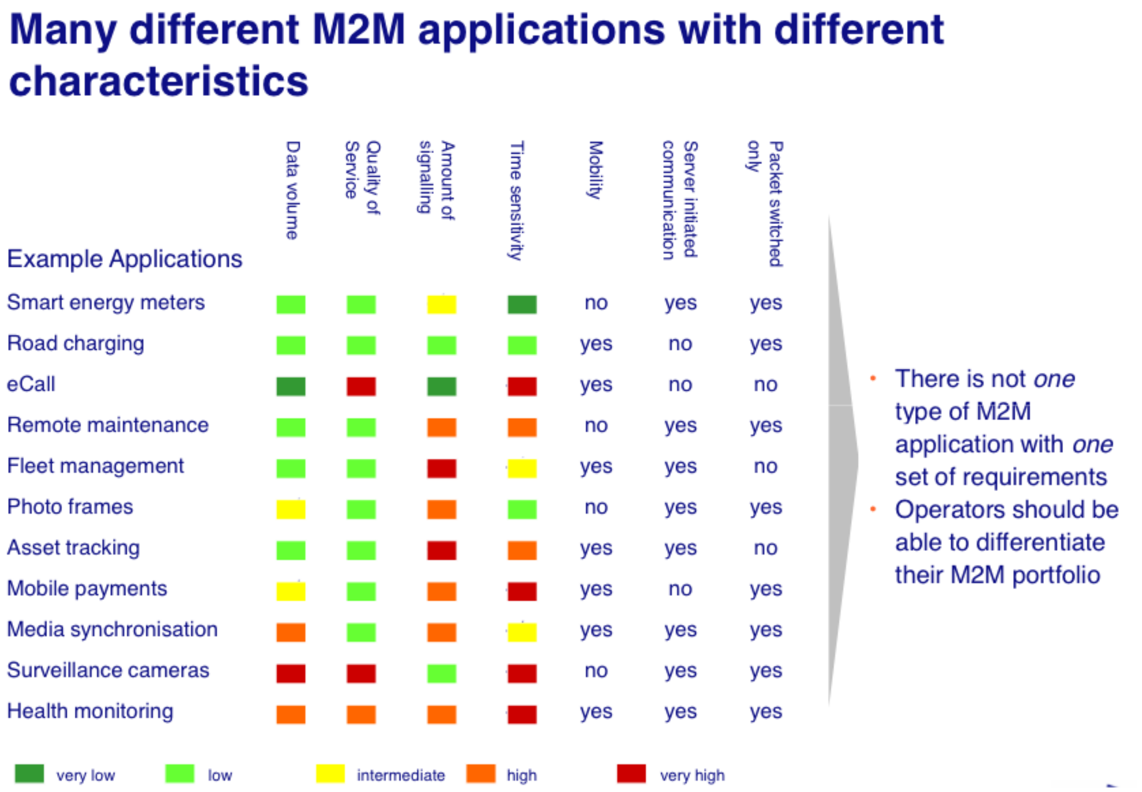

Figure 27 - Variation in M2M Requirements [46]

Another theme that has been seen in many of the use cases described above is the possibility of substantial periodic loading, as well as the possibility of substantial aperiodic loading, on operators' networks. This is further discussed in the next section, "Impacts on Telecommunication Networks."

3GPP SA1 has captured stage 1[5] requirements for M2M communications in Technical Specification TS 22.368 "Service Requirements for Machine Type Communications (MTC); Stage 1" [47] although a number of requirements are being transferred to TS 22.101 "Service Aspects; Service Principles" [48] because they are seen to be applicable and useful beyond MTC. 3GPP SA2 has capturing stage 2 requirements in TR 23.888, "System Improvements for Machine-Type Communications (Release 11)" [49] and is currently progressing normative specifications based on this study. (Work on further refining this TR has ceased in favour of progressing the normative work, but the TR has not yet been submitted to 3GPP SA for approval.)

3GPP2 has captured requirements for M2M communications in S.R0141-0 [50].

ITU-T has captured its work on Ubiquitous Sensor Networks in Recommendation Y.2221 "Requirements for support of ubiquitous sensor network (USN) applications and services in the NGN environment" [45]. ITU-T is also working a new Recommendation, Y.MOC-Reqts, "Requirements for support of machine oriented communication applications in the NGN environment" [51].

ETSI has captured its work on M2M communications requirements in ETSI TS 102 689 V1.1.1 "Machine-to-Machine communications (M2M); M2M service requirements" [52].

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5 Information on the three stage specification methodology may be found in ITU-T Recommendation I.130 "Method for the characterization of telecommunication services supported by an ISDN and network capabilities of an ISDN" available at www.itu.int/rec/T-REC-I.130-198811-I

9 Observed Impacts of M2M on Telecommunication Networks

The discussion so far has made it clear that one of the impacts that network operators will face is a tremendous increase in the volume of data they will be expected to carry. This brings two areas where problems may emerge. One is that of simple volume. Another is periodic peaks in demand when many devices access the network at the same time.

Periodic loading occurs when many devices try to access the network at the same time. A real world example was provided by KPN to 3GPP SA1 in November 2009 [53]. At this time, no significant standards for M2M were yet in place so many instances M2M communications was being provided in the form of user plane data sessions. Quoting from the submission: “We see significant peaks of signalling at precisely every hour or half hour, probably generated by automatically generated data transfers. The figure below gives an example of a Radius server load, just to illustrate the problem. Note that this problem seems to be increasing, with an increasing difference between peak and normal load.”

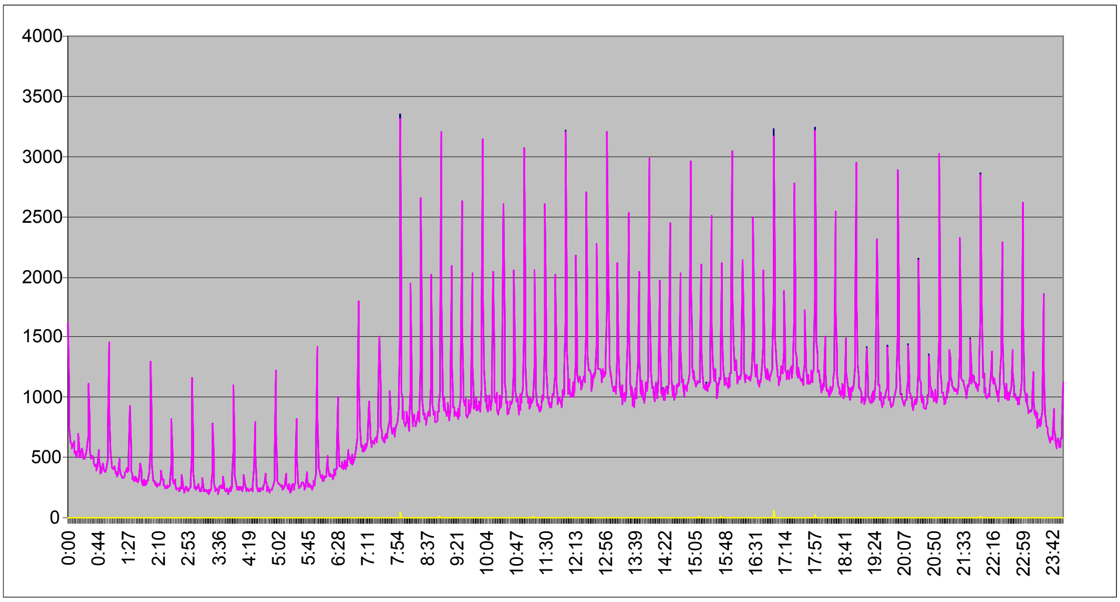

Figure 28 - Example of Periodic M2M Network Loading [53]

It is immediately apparent that a traffic pattern such as that shown above is problematic. The peak loads are much higher than the average loads. For satisfactory performance under peak loading, substantial capacity would have to be provided that would be idle for much of the time. This does not make for a good business case unless very high fees can be charged for the M2M traffic.

The reality is that M2M Subscribers, considering the high volumes of M2M devices anticipated and the nature of many of the applications, are expected to seek the lowest possible pricing. Therefore, alternatives are needed for managing these traffic loads.

Another important factor is the effects of a network outage and recovery. When a major outage occurs, as it inevitably will, there is the possibility of very large numbers of M2M devices trying to regain access to the network at the same time. When a network is restarting, it is often already stressed due to normal reconnects, and a large number of M2M devices trying to access it simultaneously is not what is needed as nodes are brought back on line.

When an attempt to initiate a data session fails, a retry may be part of the implementation, A badly implemented retry scenario in devices can result in 50,000 devices attempting to re-establish a data connection every 12 seconds. Because of the automated nature of M2M applications, they can generate very high simultaneous network access attempt load, causing disturbance of higher value services or network outages. Other data communications applications on the packet switched network may be disrupted such as streaming applications (video, audio), image applications (photos, graphics) or character-based applications (email, web browsing.) This is a real possibility today. With increasing numbers of M2M applications it will become more and more difficult to prevent overload by addressing individual M2M applications. Therefore, approaches are needed that can mange M2M traffic as a whole rather than be focussed on individual applications.

When a major power outage occurs, millions of devices may "re-boot" simultaneously, along with the network, and so overload it that it brings it down. This cycle could repeat multiple times of means are not in place to perform an orderly start up. While the image in Figure 29 is a hoax [54], it does serve to illustrate the concept of what a major outage could entail.

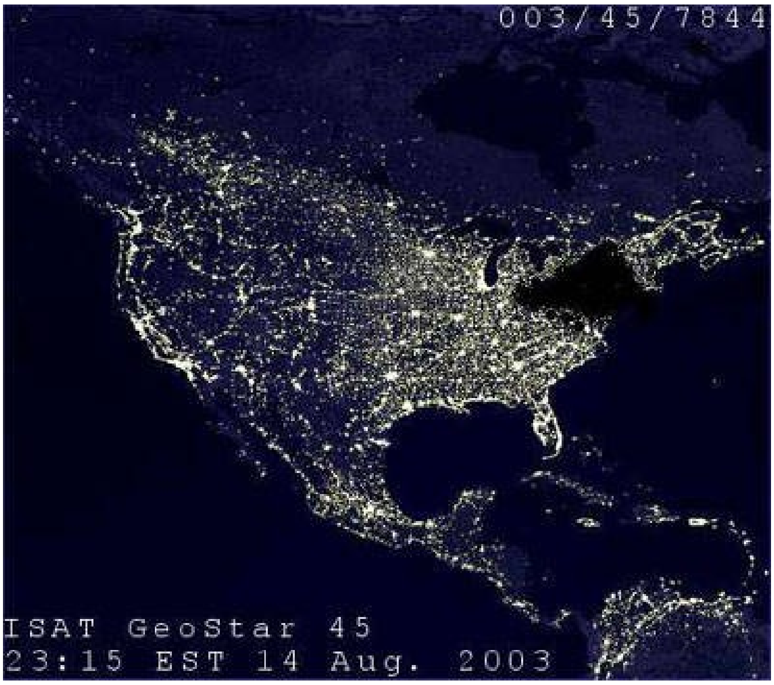

Figure 29 – Counterfeit Image of North America Power Outage

10 Smart Phones

Before looking at smart phones in more detail, it is appropriate to spend a few moments looking at what is behind the emergence of smart phones.

10.1 Definition

What is a "smart phone"?

A smartphone is a high-end mobile phone built on a mobile computing platform, with more advanced computing ability and connectivity than a contemporary feature phone. A feature phone is defined at [[55]] as "Any mobile phone that is not a smartphone." Third party applications are restricted to relatively limited platforms such as Java[6] or BREW[7].

The first smartphones were devices that mainly combined the functions of a personal digital assistant (PDA) and a mobile phone or camera phone. Today's models also combine the functions of portable media players, compact digital cameras, pocket video cameras, and GPS navigation units. Modern smartphones typically also include high-resolution touchscreens, web browsers that can access and properly display standard web pages rather than just mobile-optimized sites, and high-speed data access via Wi-Fi and mobile broadband [56].

Among all the capabilities built into a modern smart phone, one almost forgets that it can also place and receive voice calls. Indeed, the advertising for smart phones focuses almost exclusively on the data capabilities, including web browsing, email, sending graphics and video streams, etc.

10.2 Moore's Law

The evolution of electronic components has been one of startling advances in capability and reductions in cost. Moore's Law [57] is often quoted in this regard. Several measures of digital technology are improving at exponential rates related to Moore's law, including the size, cost, density and speed of components, but Moore himself wrote only about the density of components at minimum cost. Moore's Law was expressed in an article published in Electronics, Volume 38, Number 8, April 19, 1965 [58].

Despite various potential limits, the essential relationship of exponential growth in capacity, performance, etc., coupled with reduced costs, has held true for decades and may well hold true for some time to come.

One example from the author's personal experience: a computer hard drive purchased in about 1988 had a capacity of 20 megabytes and cost about $800 (USA dollars.) It is possible today to buy a hard drive with a capacity of 1 terabyte for less than $100[8]. It takes about $1.90 to buy in 2011 what could be purchased for $1.00 in 1988, that is, inflation in the USA has roughly halved the value of a dollar. In approximately 23 years, and taking some liberties with rounding the calculations:

- The capacity of a hard drive has increased by a factor of about 50,000
- The price of a hard drive has decreased by a factor of about 1,600
- The price per megabyte of hard disk drive storage decreased by a factor of 800,000

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[6] Java is a general-purpose, concurrent, class-based, object-oriented language that is specifically designed to have as few implementation dependencies as possible. See: www.java.com

[7] BREW (Binary Runtime Environment for Wireless) is an application development platform created by Qualcomm, originally for CDMA mobile phones, featuring third party applications such as mobile games. It is offered in some feature phones but not in smart phones. See: www.brewmp.com

[8] Floods in Thailand in 2011 impacted hard disk manufacturing facilities and caused significant price increases.

The above has not considered the reductions in physical size of hard drives, nor the increases in performance (seek times, transfer rates, etc.)

Figure 30 provides a graphic of the progress in processor capabilities with time, showing clear exponential progress consistent with Moore's Law.

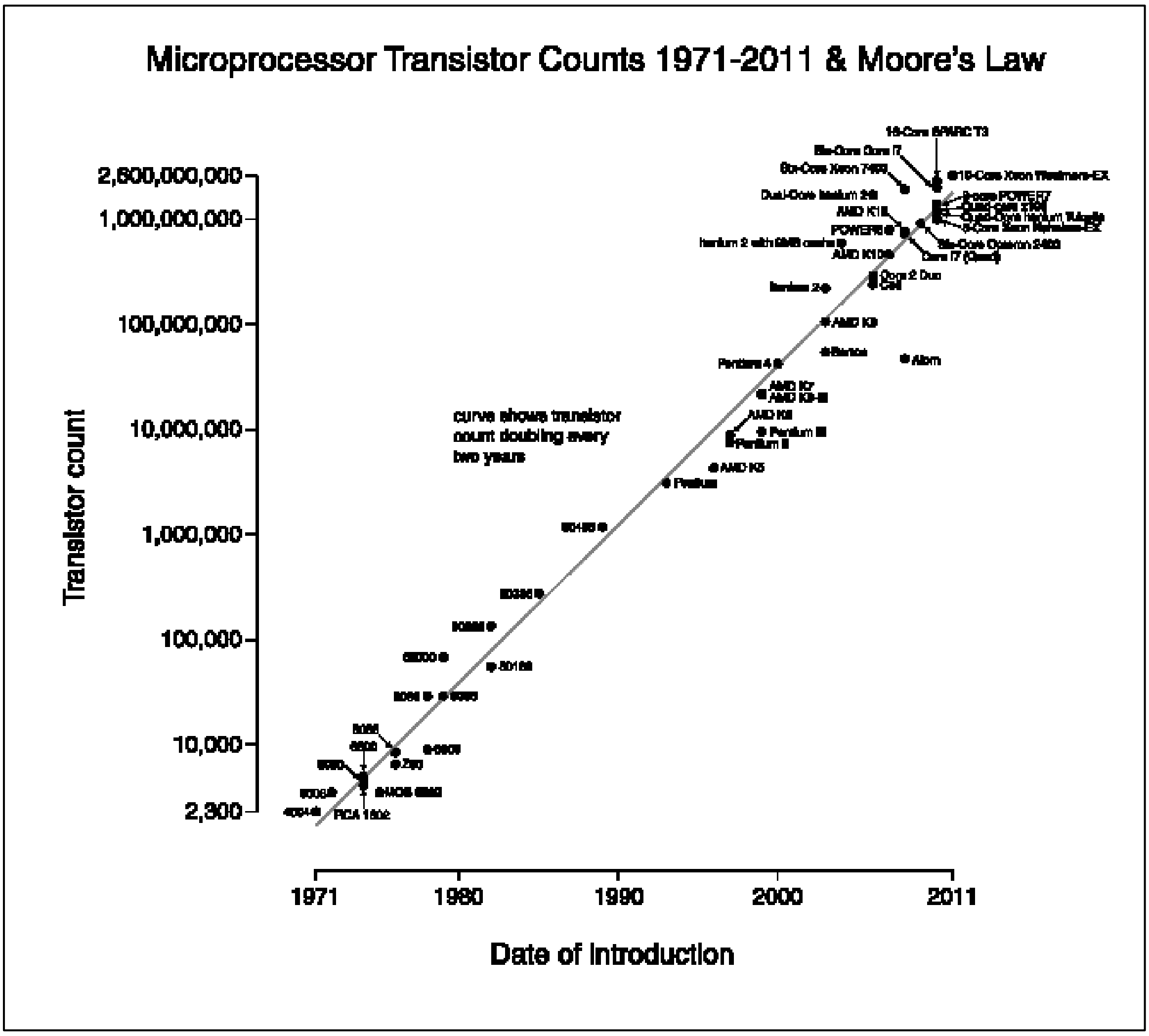

Figure 30 - Microprocessor Evolution and Moore's Law [59]

10.3 Impact of Moore's Law

What does Moore's Law mean for user equipment? Very simply, it means that it is now possible to provide extensive computing power, storage and display capabilities in a device that fits easily into a pocket or purse.

Consider several popular and recently introduced mobile phones that represent state of the art consumer products (although "state of the art" in the consumer market place can be significantly behind "state of the art" in the research and development laboratories.) These devices are much more than mobile telephones. Indeed, their ability to be used as mobile telephones is almost secondary to their capabilities as portable computers, not to mention their capabilities as portable music players and portable digital cameras.

Table 3 provides some of the technical specifications for several state of the art smart phones and Figure 31 provides illustrations of these devices.[9]

Table 3 – Technical Specifications for Selected Smart Phones

	Apple iPhone	Samsung I9000 Galaxy S	HTC Rezound
Reference	www.apple.com/ca/iphone/specs	www.google.com/nexus/tech-specs	http://en.wikipedia.org/wiki/HTC_Rezound www.gsmarena.com/htc_rezound-4099.php
Released	Oct 2011	Nov 2011	Nov 2011
Size	115.2 x 58.6 x 9.3 mm	135.5 X 67.9 x 9.47 mm	129 x 65.5 x 13.65 mm
OS	iOS 5	Android 4.0	Android 2.3.4
Weight	140 grams	145.5 grams	170 grams
Storage	16, 32 or 64GB	32 GB	16 GB
Processor	800 MHz dual core Apple A5	1.2 GHz dual core Samsung Exynos 3110 processor combining a 45 nm 1 GHz ARM Cortex A8 based CPU core with a PowerVR SGX 540 GPU	1.5 GHz (Dual Core) Qualcomm Snapdragon MSM8660
Display	3.5 inch diagonal, multi-touch, 960 x 460 pixels at 326 pixels per inch, 800:1 contrast ratio, 500 cd/m2 maximum brightness	4.65 inch diagonal, 1280 x 720 pixel	4.3 inch diagonal. 720 x 1280 pixels, 342 pixels per inch
Camera	8 megapixel with autofocus, LED flash, HD capable to 1080p at 30 fps Front camera, VGA quality, 30 fps Geotagging capable	5 megapixels, with autofocus, LED light, 1080p	8 megapixel, 1080 at 30 fps, 720 at 60 fps; 2 LED flash Front: 2 megapixel fixed focus
Radios	UMTS/HSDPA/HSUPA (850, 900, 1900, 2100 MHz) GSM/EDGE (850, 900, 1800, 1900 MHz) CDMA EV-DO Rev. A (800, 1900 MHz) IEEE 802.11b/g/n Wi-Fi (802.11n 2.4GHz only) Bluetooth 4.0	UMTS (900 / 1700 / 2100 MHz) UMTS (850 / 1900 / 2100 MHz) CDMA2000 1X (800, 1900 MHz); CDMA/LTE IEEE 802.11 a/b/g/n Bluetooth 3.0	Dual-band CDMA/EV-DO Rev. A (800 1900 MHz) LTE 700 MHz (band 13) IEEE 802.11 a/b/g/n Bluetooth 3.0

9 The data included here is current as of January 2012 and is intended to be representative only. No endorsement or other conclusion should be drawn from the devices being included here, nor should the data quoted be used as a mechanism for ranking these devices. For purposes of this technical paper, these devices should be considered essentially equivalent.

	Apple iPhone	Samsung I9000 Galaxy S	HTC Rezound
Location	Assisted GPS and GLONASS Digital compass Wi-Fi Cellular	GPS receiver	Assisted GPS
Audio playback	20 – 20K Hz	Not listed, likely similar	Not listed, likely similar
Sensors	3 axis gyroscope Accelerometer Proximity sensor Ambient light sensor	Not listed, likely similar	Accelerometer Gyroscope Proximity sensor Compass

Apple iPhone 4S Samsung Galaxy HTC Rezound

Figure 31 – Some Example Smart Phones - November 2011

While the above table and figure provide some details on a few selected “high runner” smart phones, they are by no means the only ones available. There are multiple other smart phones available, including those manufactured by Motorola, Sony Ericsson, RIM, LG, HP/Palm, Nokia, Huawei and ZTE as well as others. Operating systems include various versions of Symbian, Android, RIM, iOS, Windows and others. In particular, Canada’s Research in Motion (RIM) Blackberry series of smart phones [60] have enjoyed considerable enterprise acceptance and success.

11 Applications on Smart Phones

With the understanding that smart phones are mobile computing platforms with telecommunication capabilities, what sorts of applications can these computers support?

As general-purpose computers, the nature of the applications that can be supported is constrained by a number of factors:

- Processor capabilities
- Memory
- User interface
- Communication capabilities

A general-purpose computer's processor and memory capacity are key elements in determining what types of application programs can be supported. If an application program requires executing extensive instructions and the processor takes too long to do these, the user will have an unsatisfactory experience. These program instructions may be simply mathematical in nature or, more likely considering the capabilities of desktop and laptop computers and the applications they support, display rendering instructions.

11.1 Quality of Experience

This leads to consideration of a concept known as “Quality of Experience” or QoE. Quality of Experience may be defined as a subjective measure of a user's experience and satisfaction with a service (e.g., web browsing, phone call, media stream, etc.) QoE tries to measure customer perception as a quality parameter (e.g., time to load and display a web page) but differs from Quality of Service (QoS) that objectively measures the service delivered. A service provider may be living up to the QoS terms of a contract (rating high in QoS) but the user may be very unhappy (causing a low QoE), and vice versa."

Users see mobility as highly valuable, as has been discussed earlier in this document. They are willing to give up some aspects of Quality of Service compared to a laptop or desktop situation because of the value placed on mobility. In mobile telephones, this was originally in the form of poorer voice quality, lower likelihood of call completion, and the possibility of calls being dropped.

For smart phones, these factors still apply for voice calls, but now the form factor of the device becomes more important and the data capabilities of the device become more important.

The form factor is best expressed as a reduced screen size. This is offset by high resolution such as seen in the specifications in Table 3. However, even with high resolution, the absolute screen size poses limitations. Is it realistic to try to watch a high definition video on a screen that is clearly not capable of producing a high definition image? Are users able to properly “see” an HD image if it is provided at the size of a smart phone? Are there limitations in human vision that need to be factored in, particularly for older users who may have presbyopia or other vision limitations? It is the author's view that screen size limitations and related human factors must be taken into account in order to ensure a good Quality of Experience.

On the other hand, smart phones have addressed one problem rather well. The user interface of mobile phones has been greatly limited in this regard for some time. A ten digit keypad (plus * and #) is not conducive to complex instructions. A number of feature phones have addressed this by providing a keyboard for entering data and instructions, notably research in motion products but also other manufacturers' high end products. Nevertheless, having to enter all instructions on the device suing a keyboard and perhaps a few other dedicated or programmable buttons is not especially satisfactory.

How have smart phones addressed this area? With touch screens. This mode of inputting user instructions is highly flexible because it enables an easy to understand set of options for the user to be displayed and selected from. Touch screens can also be used to provide keyboards for data and text input, and the nature of this interface enables a much greater degree of flexibility to accommodate various alphabets since the display can be modified to show the characters, as opposed to the fixed labels that are provided on fixed keyboards.

What is critical in the success of a smart phone and the applications that may be factory installed or subsequently downloaded is that the user interface is intuitive, easy to figure out and easy to use, especially for the majority of the population that is not deep into computing and programming and other arcane aspects of IT.

11.2 Smart Phone Communication Capabilities

Having discussed processor capabilities, memory and the user interface, it is time to turn to communication capabilities and how these are used by the various applications that may be installed on a smart phone.

2G networks provide voice capabilities and some limited data capabilities. 3G networks provide voice and data capabilities. 4G (LTE or IMT-Advanced) networks are data networks with voice capabilities. As each generation has been specified, deployed and used, the data capabilities have increased. LTE networks can provide high data rates but these must still be shared among all the users in a given serving area (usually a cell) so will not be able to latch the data rates that a use sees when using a desktop or laptop computer.

This has led to work on a variety of approaches to handle high data demand. These include using alternate means such as WiMAX and Wi-Fi but this brings with it issues in managing transition between systems in addition to hand-off between access nodes in any given system.

In addition to the above, smart phones typically also support Bluetooth for very close device connectivity such as headsets and hands-free units. Bluetooth may also be used for smart phone-to-smart phone and smart phone-to-PC interaction.

11.3 Smart Phone Applications and Data Communications

How important is data communications for application programs installed on a smart phone? The answer is: “It depends.”

The nature of the application will significantly affect the smart phones demands on data transfer, both to and from the device. Some applications will be entirely local and, once installed, will not place any demands on the communications capabilities of the smart phone. Other applications will do most of their work locally but will need to interact with a server from time to time to synchronize data. Typical examples are calendars and contact list managers that automatically synchronize across devices. Still other applications utilize considerable data transfer for short periods followed by long periods of little or no transfer. Web browsing and email fall into this category, as do photo data base uploads and downloads. At the next level are multi-device interactions where data needs to be transferred among many devices frequently and quickly. Multi-player gaming is an obvious example, with a wide range of data volume depending on the particular game. The final category is media streaming which requires a more or less constant data rate to transfer audio or video or both to or from a device. Listening to a radio station or other audio source, or watching a movie or other video source on line are examples of essentially one-way data streams. Multimedia teleconferencing makes this bidirectional, and may also add other bearers for graphics sharing or display, or other purposes.

Is it possible to control what users do? To a degree, but not completely. The “rule of thumb” about users is that they will always do something that is unexpected.

Users will install applications they find useful, interesting or merely as something to try. The source of applications being downloaded can be constrained, such as Apple does for iPhones with its App store, but the number and types selected are under the user's control. As of the end of the third quarter 2011, the Android Market had 319,161 active applications compared to 459,589 for the Apple App Store. (As of 28 January 2012, Apple's web site indicates there are now more than 540,000 applications available [62].) The churn rate, or applications that have been removed from an app store, was significantly higher for Android at 37% as compared to 24% for the App Store but most of these were "free" apps [61].

This is the list of Application categories as used by Apple taken from iTunes [62]:

- Books
- Business
- Education
- Entertainment
- Finance
- Games
- Health & Fitness
- Lifestyle
- Medical
- Music
- Navigation
- News
- Newsstand
- Photo & Video
- Productivity
- Reference
- Social Networking
- Sports
- Travel
- Utilities
- Weather

Applications for Android-based smart phones are also available in substantial numbers [63]. The categorization differentiates between Applications and Games and then adds sub-categories:

- Applications
  - Books & Reference
  - Business
  - Comics
  - Communication
  - Education›
  - Entertainment
  - Finance
  - Health & Fitness
  - Libraries & Demo
  - Lifestyle
  - Live Wallpaper
  - Media & Video
  - Medical
  - Music & Audio
  - News & Magazines
  - Personalization
  - Photography
  - Productivity
  - Shopping
  - Social
  - Sports
  - Tools
  - Transportation
  - Travel & Local
  - Weather
  - Widgets
- Games
  - Arcade & Action
  - Brain & Puzzle
  - Cards & Casino
  - Casual
  - Live Wallpaper
  - Racing
  - Sports Games
  - Widgets

Whether one agrees with these classifications or not is unimportant. What is important is that there are multiple categories to assist in finding what one needs or wants. Figure 32 and Figure 33 provide examples of how apps are displayed on Android and iOS-based smart phones. The style is different but the essence is the same: there are many apps available and the user can select the one he or she wants by looking through the screen where they are listed and selecting the one to be executed. All smart phone and table computer operating systems provide variations on this approach.

Figure 32 - Some Android-based Smart Phone Apps [64]

Figure 33 - Some Apple iOS-based Smart Phone Apps [65]

11.4 A Further Look Into the Smart Phone Application Categories

The following listing shows a number of applications or types of applications within each of the categories using the Apple iPhone list. Again, it does not matter whether one agrees with the categorization. Rather it is important to note the extensive range of applications. This range is what we will shortly be examined to assess what it means to mobile networks.

- Books: this category includes both general-purpose e-book reader applications and stand-alone e-books.
- Business: mathematics programs for various functions including not only accounting but also tools related to the type of business, dictation, real estate title search agents for specific cities (e.g., Austin, Texas), time sheet managers, legal services, etc.
- Education: reading, writing, spelling, grammar, arithmetic, language, history, colouring, drawing, etc., courses for various age levels, various aptitude tests, flash cards for various topics, etc., and in various languages (i.e., material intended for education in countries where the mother tongue is not English)

- Entertainment: jokes, comics, trivia games, book information (e.g., "The Girl With the Dragon Tattoo": trivia questions, character summaries, family tree, book summary, author information), movie and film information, local theatre show times, arts centre information and program times, ticket purchase applications, serious or not so serious applications (e.g., "Mayan 2012 Countdown"), etc.
- Finance: loan and mortgage calculations, personal finance and budgeting tools, expense managers, cell phone bill minders, Big Mac Index, stock market and other financial data, etc.
- Games: download game, register. Check help resources on line. Post high-scores. Multi-player games, cooperative or competitive.
- Health & Fitness: fitness logs, pedometers, weight management tools, exercise planners and trackers, calorie counters, blood pressure tracking, diet planners, pregnancy resources, etc.
- Lifestyle: shopping tools, clothing sizes, ecology tools, restaurant menus and reviews, hobby aids and reference works of various types, shopping assistants including access to retail store shopping systems (including bar code scanning to get product reviews, store location and other information, advertising for specific stores, etc.), recipe managers, etc.
- Medical: reference material, antidotes, blood pressure and weight guidance, medication monitors and schedule assistants, medical terminology, anatomy and other medical references, baby and child development guides, parenting guides, etc. Bluetooth device may monitor certain parameters (heart rate, blood pressure, blood sugar, etc.) with data collected and analysed by an application that reports periodically or urgently according to the need.
- Music: numerous radio stations that web cast their programming, programming information, musician information, discographies, play lists, learn to play various instruments, scales, metronomes, music timers, audio mixers, instrument references material, music identifiers, etc.
- Navigation: maps, routes, city guides, country guides, sites of interest in numerous categories, fuel and other resources for driving, parking spot locaters, construction alerts and other road condition information, emergency applications, transit information (schedules, next bus or train at this stop), etc.
- News: news feeds (CNN, BBC, CBC, CTV, etc.), personalized magazines created from preferences, etc.
- Newsstand: electronic editions of newspapers and magazines across virtually all interests.
- Photo & Video: organizers of various types, add on applications to enable editing and effects, etc.
- Productivity: password managers, diaries and calendars, to do lists with reminders, note and list applications, time loggers, clock and timing functions, etc. Calendars: schedule meetings, appointments, etc., and synchronize these across multiple devices. Contacts: automatically (e.g., from email) or manually enter contact information (name, positions, company, phone numbers, email addresses, URLs relevant to the person or company, notes on when and how met, interests, birthdays and anniversaries, and anything else that one might wish to include, and synchronize these across multiple devices.
- Reference: dictionaries and thesauruses in multiple languages (including Egyptian hieroglyphics), constellations, zodiac, mushrooms, wines, Scotch and other whiskeys, rules for games of all types, how to for numerous types of projects and repairs, automotive reference data, etc.
- Social Networking: access to various sites including Facebook, LinkedIn, Twitter and many others[10]

[10] Wikipedia offers a list of social networking sites at http://en.wikipedia.org/wiki/List_of_social_networking_websites but not all of these have related smart phone applications.

- Sports: scores and team standings for many sports and locations, team rosters, information on individual players, rules for various sports, game schedules, Mobile Avalanche Safety Tools, etc.
- Travel: transportation schedules, hotel and restaurant locations and information, guides to cities and countries, location and hours for various travel services (gas stations, etc.), translation tools for menu items, embassy and consulate locations, guides to various tourist attractions (e.g., Disneyland), flight trackers, currency exchange, etc.
- Utilities: calculators, tools (e.g., flashlight applications using camera's LED flash), measuring devices and tools such as levels, rulers, etc., that make use of the smart phone's sensors, driver logbooks,
- Weather: local, regional and national forecasts, weather warnings (tornadoes, hurricanes, typhoons, thunderstorms, snow and rainfall, wind), UV warnings, moon phases, tide tables, unit conversion tools, weather reference tools of various types

12 Evolving Computer Communications

Smart phone applications will have a range of communication needs, just as applications on desktop personal computers do. A review of the situation for general purpose desktop and laptop personal computers will set the stage for a discussion on supporting the communication needs for applications installed on smart phones. There are two aspects to this. One is the general approach to providing communications. The other concerns the specific needs of the individual applications themselves.

12.1 Desktop (i.e., non-Mobile) Computers

Desktop computers have been the norm for many years and remain common. Laptop computers were limited in capability and were seen more as adjuncts to a desktop computer than as stand-alone devices. This has changed over time as progress in miniaturizing components has made it possible and then practical to shift to using a laptop as one's main computer. This is well illustrated by the shift in sales from desktop to laptop computers as reported by Amazon in relation to year-end 2008 sales [66].

With desktop personal computers, the typical situation is that at least an email program and a web browser will be part of the suite of applications installed. In a desktop environment, the typical users does not give any thought to the communication needs of the applications installed since the machine is very likely connected via a wired interface (typically Ethernet) into the communications infrastructure. The same comments apply to a laptop in a workplace situation: the laptop is typically "docked" and is used essentially as if it is a desktop personal computer.

When a desktop computer is used at home, its communication need are often met by means that lag in time those used in the workplace: when Ethernet became common in the workplace, home users still often relied on modems.

12.2 Laptop (i.e., Mobile) Computers

When a user takes a laptop out of the office environment ("undocks" it), then there will be increased awareness of the communications needs of the applications being used and actions that are needed to make those communications work. These communication needs may be met by use of a modem, either built in (had become the norm but is no longer included in newer laptops) or on a dongle (for adding the capability to laptops without built-in modems.) This approach offers only rather low speed data capabilities and therefore a relatively poor "Quality of Experience" for the user, especially with the high graphics content of many web pages and the increasingly frequent use of graphics in emails along with attachments that always seem to get larger. As a result, the use of modems to carry relatively low speed data on the PSTN is declining rapidly in markets where higher data rate systems are readily available, particularly western Europe, North America and a number of Asia-Pacific countries, notably Japan and South Korea.

An attractive alternative to using modems on dial up connections is Ethernet. Communications facilities may be accessed in some hotels through plugging an Ethernet cable into the appropriate port on the laptop. This typically offers similar or nearly similar performance to that seen in the office workplace, and hence similar Quality of Experience. However, end users may be charged by the hotel for use of these facilities. The charges may range from free to as much as EUR20.00 per day.

Home users seeking greater capacity and improved performance have welcomed DSL and cable-based systems that use a modem suited to the bearer and provide an Ethernet interface towards the desktop or laptop computer.

What is much more common today is the use of wireless communications. Wi-Fi [67] is available in many locations, including shopping centers and coffee shops, as well as in public areas such as airports, train stations, and is even provided in some municipal core areas courtesy of the local government. Wi-Fi is well suited to nomadic use, that it to situations where the user is stationary while accessing communications facilities but not when the user is moving. An alternative to Wi-Fi is WiMAX [68], which offers longer range, better data rates, and use of licensed spectrum and therefore much reduced likelihood of interference resulting in poor or no performance.

In many workplaces, enterprise Wi-Fi is provided to enable employees (who are today much more likely to have enterprise-provided laptops) so that the enterprise facilities and servers may be accessed from anywhere within the enterprise, such as a meeting room, the cafeteria, or when visiting another person's office.

While there is work underway towards supporting mobility with both Wi-Fi and WiMAX, the reality is still that they need to be considered suitable primarily for nomadic usage.

In step with the proliferation of Wi-Fi, home users have shifted from hard-wiring their desktop and laptop computers to their DSL or cable modems to using a local Wi-Fi access point. This access point is connected by Ethernet to the modem but the computers (now frequently more than one!) are connected to the access point wirelessly.

As the data capabilities of mobile networks have advanced, there has emerged an additional type of data communications access mechanism especially suitable for laptops outside the workplace or home environment, i.e., when roaming to a customer location, conference, etc. This is the data dongle designed to access the data capabilities of the cellular or mobile network. Such devices are essentially cell phones without voice capability. They have SIM cards (inserted as a discrete device or permanently embedded.) They support mobility and roaming. They are capable of accessing a variety of technologies depending on what is available in the area where they are located, such as LTE or 3G or 2G data. While they may not yet offer the fata rates that wired solutions can provide, the inherent desirability of mobility makes them very attractive.

12.3 Tablet Computers

The technological improvements that have enabled the production of high capability laptops have at the same time enabled the emergence of tablet computers [69] with the Apple iPad [70] being the first commercially successful such product. A tablet computer is a general-purpose device with a form factor that focuses on a touch-screen for both display and input, and that typically lacks a keyboard and a mouse or similar pointing device (track pad, track ball, etc.) although these can be add-ons. The almost instantly iconic Apple iPad is the device most often pictured but many competing devices have emerged.

Clockwise from top: Samsung Galaxy Tab, Apple iPad, HP TouchPad, RIM Playbook

Figure 34 - Example Tablet Computers

12.4 Smart Phones

As already discussed, the smart phone has emerged as a general-purpose small form factor device that started as a mobile voice terminal. Therefore, it is to be expected that the communications needs of the applications on smart phones will be similar to the communication needs of similar applications on desktop and laptop computers.

However, there are several aspects that are dissimilar. First of all, the much smaller form factor (screen size) of a smart phone means that it cannot display as much information at a size that makes it readable as is possible on a desktop or a laptop. Secondly, since it started out as a voice device, the evolved user equipment carries with it the expectation that the applications will work in a full mobility scenario. Thirdly, the nature of the applications themselves will be different from those on a desktop or laptop, driven by the form factor, mobility, and especially by the needs of the user who must be presumed to be "on the move" when both the communications and the applications themselves are designed.

Since smart phones are presumed to make use of the mobile network, it is necessary to take account of the capabilities of the mobile network, more specifically the finite data capacity within a given cell and the vagaries of radio transmission as users move about, especially in congested metropolitan environments where there may be many large buildings which can interfere with radio propagation, and high user densities which can lead to radio resource congestion.

13 Communication Needs of Smart Phone Applications

In order to better understand the potential impacts of smart phone applications on mobile networks, it is appropriate to review their likely communication needs. Smart phone typically have email clients and web browsers installed, and often many other applications.

The characterizations listed here are not intended to be exhaustive but rather to be representative.

- Email
    - Some email servers push messages to the device's client as they arrive.
    - Some email clients periodically query the server for new messages.
    - Receive incoming messages.
    - Send outgoing messages.
- Web browser
    - Bring up a "home page" (default or user selected.)
    - Send request for a page.
    - Receive page for display to user.
    - Support plug-ins for java scripts, audio or video streaming, other purposes.

For both the above, the demands on the communications infrastructure will consist of periodic brief exchanges of small data ("any messages for me?"), moderate data (email message, web page) or potentially significant data (picture, audio or video stream.)

13.1 Communication Needs Within Smart Phone Application Categories

The following application category listing and analysis is again based on the list Apple uses as a convenient base.

An initial "Common" grouping has been added to capture items that are common to multiple categories.

- Common
    - Select and download an application. If applicable, verify licensing and payment.
    - Updates (added capabilities, bug fixes, etc.) requiring download and installation of a fresh copy of an application.
    - Includes synchronization between the smart phone and a server to check what the current version is, and to verify licensing if applicable.

- Downloaded documents and applications may vary considerably in size.

The following list expands on the categorization.

- Books
  - Download an e-book: select an e-book, pay for it and then receive the file for perusal. E-books may vary considerably in size.
  - Synchronization with a server when the e-book application is started.
  - Statistics gathering and transfer to the server for, e.g., “frequent reader” loyalty programs or similar services.
- Business
  - Some applications will run locally and so only selection and download require communications activities.
  - Reference managers will need interaction with a server to find the appropriate reference (legal document, real estate listing, etc.) and then download it to the smart phone.
  - Downloaded documents and applications may vary considerably in size.
- Education
  - Monitor usage, progress.
  - Run tests and record results on a server.
  - Enable interaction with a (possibly remote) teacher: ask a question or offer an answer to a question.
- Entertainment
  - Periodic downloads (daily joke, comic strip, etc.)
  - Interaction with servers for information on reviews, availability and times in local theatres, buying tickets
  - Watch movie trailers
- Finance
  - Periodic updates on stock market indices and specific socks or securities, either by querying a serve or by pushing data based on triggering parameters.
  - Interaction with a server to buy or sell securities.
  - Information on availability of invoices, download invoices.
- Games
  - Single-player: download the application and then no data transfer required unless one seeks help or hints or wants to record a high score other than locally.
  - Multi-player: share data (actions, etc.) with other players in real (various role playing games) or near real time (e.g., chess match.)
- Health & Fitness
  - Download and then maintain local logs for diet, exercise, weight, etc.
  - Fitness Centre membership: book participation in group sessions, or individual training sessions or other services
- Lifestyle
  - Catalogue downloads, either a page or section at a time, or complete catalogues.
  - Interact with a server to select a product or products, arrange shipping and payment.
  - “How to” manuals and other reference material downloads.
  - Bar code scanner: interact with server to link code to a product.
  - Check others’ reviews of a product or service of interest.
  - Provide reviews of products purchased or services used.
- Medical
  - Download reference material of all types.
  - Data from Bluetooth device may trigger periodic or urgent download of collected data.
- Music
  - Audio streaming of web-based radio stations.

  - Download music files (and other media files) from servers.
  - Interact with servers for information on musicians, music, concert dates and locations.
  - Purchase tickets.
- Navigation
  - Download maps, guides, and resources.
  - Update previously downloaded maps, guides, and resources.
  - Route information (road conditions, construction delays, congestion, etc.) based on location.
  - Download bus, train, and airline schedules.
  - Obtain status (next bus, train, flight ETA.)
- News
  - Interaction with server to set up interests profile and other parameters as may be needed in the profile.
  - Real time news updates: pushed[11] to user equipment.
  - Check news as desired (pull.)
  - Alerts that a news item is waiting and can be retrieved based on the user's interests profile.
- Newsstand
  - Retrieve electronic edition of newspaper or magazine.
  - Edition of newspaper or magazine pushed to user equipment.
- Photo & Video
  - Upload photos and videos to a social networking web site or to a server specifically set up for this purpose.
  - Interact with a server to set up or modify a profile dealing with alerts on others' uploads, pushed files, etc.
  - Receive alerts when designated users post photos or videos.
  - Retrieve downloads of photos and videos on demand.
  - Receive pushed downloads of photos and videos per profile parameters.
- Productivity
  - Synchronization of data across multiple devices (calendar, to do lists, reminders, contacts, etc.)
  - Inclusion of enterprise-specific information in the synchronized data.
  - Password manager synchronization to enable access from multiple devices.
- Reference
  - Requests for definitions, synonyms or antonyms.
  - Responses to requests may be brief (most dictionary definitions) or lengthier and more complex (e.g., rules for a game, how-to manual.)
- Social Networking
  - Updates on a user's profile.
  - Recording of activities, thoughts, ideas, events, etc., per the purpose of the social networking site. (These may be of limited size, e.g., the 140 character limit of Twitter [71], or may be larger and more open ended such as Facebook, LinkedIn, etc.)
  - Uploading of photos or videos to the social networking site for viewing by selected users. (The selection may be one person, a few, all "friends" or may include everyone. This will vary by the capabilities provided by the site being used.)
  - Notifications of activity of selected users (e.g., Facebook "friends.")

[11] A "push" is delivery of information to a user's device without the user specifically requesting that information be provided immediately prior to the time it is sent. Typically, "pushed" information is sent to the user's device during otherwise "quiet" periods, although when a "quiet" period actually occurs may be subject to the specifics of the application involved.

- Sports
  - o Interact with a server to set up or modify a profile dealing with alerts on specified sports events, team events or individual athlete events.
  - o Download an audio or video clip of a particular sports highlight (e.g., when the Ottawa Senators ice hockey team scores a goal against the Toronto Maple Leafs ice hockey team.)
  - o Download streaming video and audio of a sports event as it takes place.
  - o Download a video and audio file of a sports event to watch at some time after the fact.
  - o Consult servers for specific data on game schedules.
  - o Purchase event tickets on line.
- Travel
  - o Obtain schedules for bus, train, airline companies, either for selected routes, dates and times, or complete schedules.
  - o Obtain menus for restaurants either in close proximity to the user, or for a specific location indicated by the user.
  - o Check availability and pricing of hotels, bus, rail and airlines.
  - o Check times and other data for tourist attractions (opening dates and hours, admission prices) and cultural activities (theatre and other event program times and dates, admission prices, etc.)
  - o Check others' reviews of travel options, hotels, etc.
  - o Reserve and pay for travel and accommodation.
  - o Purchas tickets to sights and events.
  - o Provide own reviews of travel services and facilities used.
- Utilities
  - o Identify utilities of interest: browse by category or grouping or other parameter.
  - o Select, pay for and download the selected utilities.
- Weather
  - o Check current and forecast weather for current location or for a specific location.
  - o Receive weather alerts and warnings supplementary to what is typically covered through Public Warning Systems (PWS) such as ETWS, CMAS, KPAS and EU-Alert[12], such as road conditions, UV levels, etc.
  - o Retrieve data on tides, moon phases and other cyclic phenomena.
  - o Retrieve historical weather data, e.g., for comparison purposes.

13.2 Additional Applications

To the above must be added existing Short Message Services (SMS) and VoIP service such as Skype [72]. In particular, Skype can be a problematic application for several reasons. The obvious one is data streaming to carry voice and video. The less obvious ones are participation in large chat rooms such as "3GPP-SA2" (which has 210 participants as this is written) which provides a updates to every participant whenever an entry is added in the chat by any of the participants, and to updates on participants (contacts) which indicate when any identified contact in a Skype list is active.

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[12] ETWS: Earthquake and Tsunami Warning System (Japan), CMAS: Commercial Mobile Alert System (USA); KPAS: Korean Public Alerting System; EU-Alert European union PWS.

Between these two aspects, Skype can overload both the user and control planes of a mobile network.

13.3 Smart Phone Application Behaviours That May Impact Mobile Networks

From the above, it is possible to identify application behaviour where mobile networks may be adversely affected. These are:

- Frequent idle-active mode transitions
- Frequent live updates (mobile originated and terminated ("push services"))
- Periodic keep alive messaging (mobile originated and terminated)
- Frequent start and stop of services
- Frequent small data transmission
- Bursts of data services resulting in deliberate or accidental denial of service
- Large downloads of data and media files, software updates and similar items

Some mobile data applications might result in adverse impact to the mobile network, e.g. due to frequent idle-active mode changing, frequent start or stop of services, small data transmission, frequent live update, transmission of data burst. Hence, the network (both RAN and CN) may experience a flood of signalling and data traffic.

The above list was prepared only a few years ago but is already showing its age. What it is missing is the "data tsunami" that all the M2M and smart phone applications are bringing to mobile networks.

14 Data Tsunami

Figure 35 - Tsunami Warning Sign

There are some interesting perspectives in several references. At LISA'06 (20th Large Installation System Administrator Conference, Washington, DC, USA, 3-8 December 2006), a presentation was given entitled "Drowning in the Data Tsunami." The authors are Lee Damon, SSLI Lab, University of Washington, Seattle, WA, USA, and Evan Marcus, Director, Tech Sales, QD Technology, Rutherford, NJ, USA. The first part of the paper provides excellent insight into the issue of what data is recorded in relation to costs and ability to retrieve it, followed by some astute observations on the rapidly increasing volumes of data that users generate and wish to store but the increasing problems in storing, accessing and retrieving the desired key piece of data from amongst all the (often unimportant clutter of) data being stored. While the presentation is not targeted at mobile networks, much of what it covers is relevant. The presentation is available at [73].

A more recent item in the technical media looks at what AT&T is doing in order to address the problem of the data tsunami. Wi-Fi is identified as a key element in managing the volumes of data anticipated [74]. This article includes a set of slides by Nokia Siemens Networks (NSN) which also appears on a blog run by NSN [75]. A key part of the message in each of these is that mobile networks need to handle 1000 times the traffic they currently do by 2020. The presentation provides perspectives both on where this traffic comes from and what can be done to deal with it, focussing on increased spectrum and advanced radio mechanisms to deal with interference. These will be important but network based approaches will also be required and these are discussed later in this technical paper.

15 Observed Impacts of Smart Phones on Telecommunication Networks

A number of real network measurements have been shared with 3GPP as it explores the impacts of non-MTC data applications and this is captured in 3GPP TR 22.801 [76][13]. Annex C of this TR is especially appropriate in this context so it is reproduced here in its entirety as preferable to trying to restate the material in new words.

Annex C:
Data application impact on real UMTS networks

Impact of PS signalling on the network

An analysis was obtained by monitoring network performance counters at urban RNCs of two different operators across multiple days. Network resource utilization, traffic, and signalling counters are analyzed.

Breakdown of DL power at the base station in Release 6

Figure C-1 is a graphic representation of downlink power utilization obtained on an UMTS Release 6 network consisting of about 600 cells. The measurements were conducted over a period of several weekdays (excludes weekends) during the time segments when traffic load is high - from 8 am to 10 pm in each of those days.

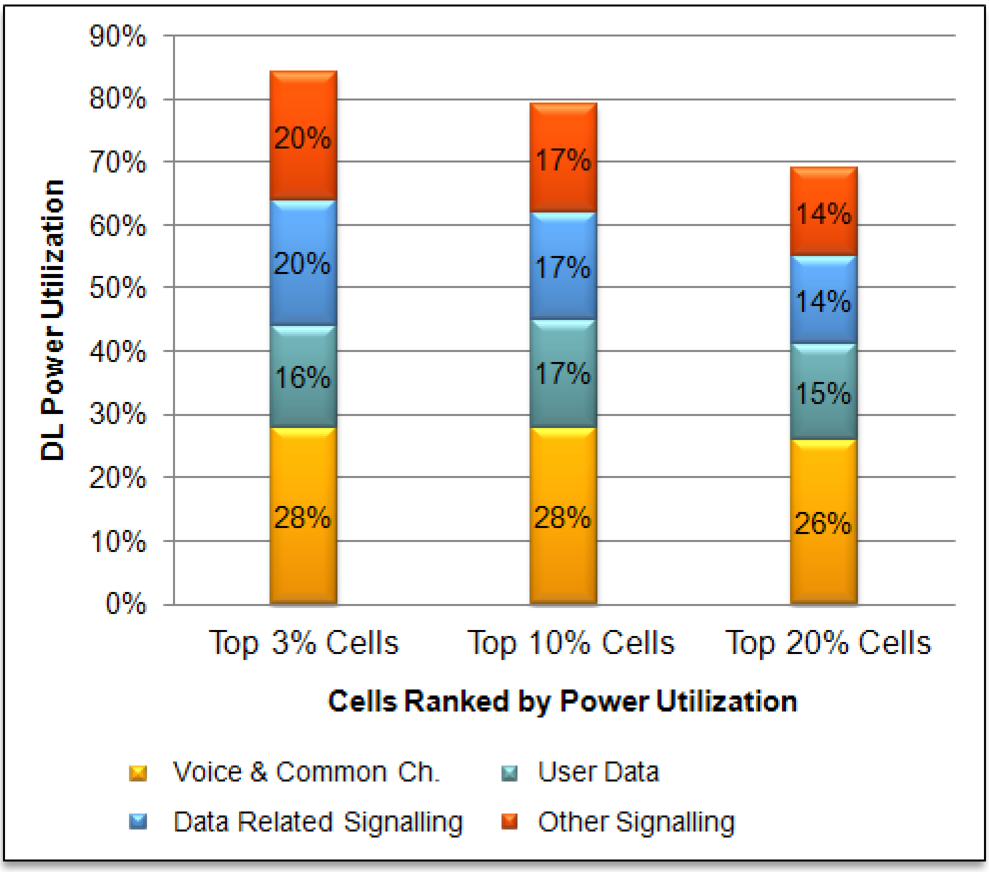

Figure C-1. DL power utilization

The statistics shown were calculated from network counters, which compute total energy used, yielding average power. The three categories of cells shown are based on maximum power utilization (e.g. "Top 10% Cells" refers to the 60 of the 600 cells that were most heavily utilized in terms of downlink transmit power). The percentages shown are relative to maximum DL power rated for the NodeB transmitters.

Transmit power is broken down into 4 categories as shown:

[13] Note that 3GPP TRs with numbers allocated in the nn.800 group are not intended to be used as reference material outside 3GPP, that 3GPP actively discourages this, but that they remain fully accessible on the 3GPP web site.

"Voice & Common Ch." includes power of common/broadcast channels (CPICH, SCH, SCCPCH (PCH, FACH), etc.), in addition to power required for carrying AMR voice frames

"User Data" refers to power consumed by user payload carrying packets

"Data Related Signalling" refers to power for control plane signalling associated with PS Data (non-voice) communication (call setup and in-call signalling), i.e. signalling related to setting up connections, scheduling user payload transmissions, and connection state transitions directly relatable to transmission of user payload data

"Other Signalling" refers to power for signalling associated with other services (Voice, SMS, Registrations, etc.)

R99 PS Data traffic is negligible in this network. Hence, power associated with R99 PS Data is not shown in Figure C-1.

Similarly, simultaneous PS and CS sessions constitute a small part of total traffic and they are captured under PS Data power.

Median CS call holding time is 60 – 80 seconds.

Some key data and findings are that, for the 10% of the cells that are the most heavily utilized,

34% of DL power is used for signalling

PS Signalling accounts for 50% signalling volume, 17% of DL power

Other signalling (registration, voice, SMS) accounts for another 17% of DL power

In summary, Data Related Signalling accounts for a very significant part of the signalling volume/impact. That impact is most pronounced in heavily utilized cells, where PS control signalling energy is equal or larger than user payload carrying energy.

Expected performance in Release 8

3GPP Release 8 (HSPA+) features aim to reduce PS Data related signalling.

Performance enhancing features introduced in Releases 7 and 8 define new UE connectivity states and allow for longer UE state transition timer settings, so that observed user activity patterns do not translate to parallel radio access network signalling associated with state transitions. These performance gains vary somewhat with timer settings and cell-to-cell (e.g., cell with predominantly high speed vehicular traffic vs. cell with predominantly indoor coverage).

Disproportionate impact of PS data communication

Another very relevant finding is that PS data communication activities have an impact on the UMTS that is higher than what the penetration of UEs designed for PS data applications in the network would suggest. In other words, as showed for example in Figure C-2, even a modest penetration (16%) of these UEs causes a very large presence (59%) of PS Calls. As the number of applications for data centric devices increases, and MTC device proliferation ramps up, the number of PS calls per UE is likely going to be increasing over time. For reference, the data presented in the Figure C-2 were collected in the spring of 2010.

Figure C-2 represents data collected using OSS performance monitoring tools in urban RNCs of selected networks: Operator A network segment monitored is comprised of 170 cells, and Operator B of 480 cells.

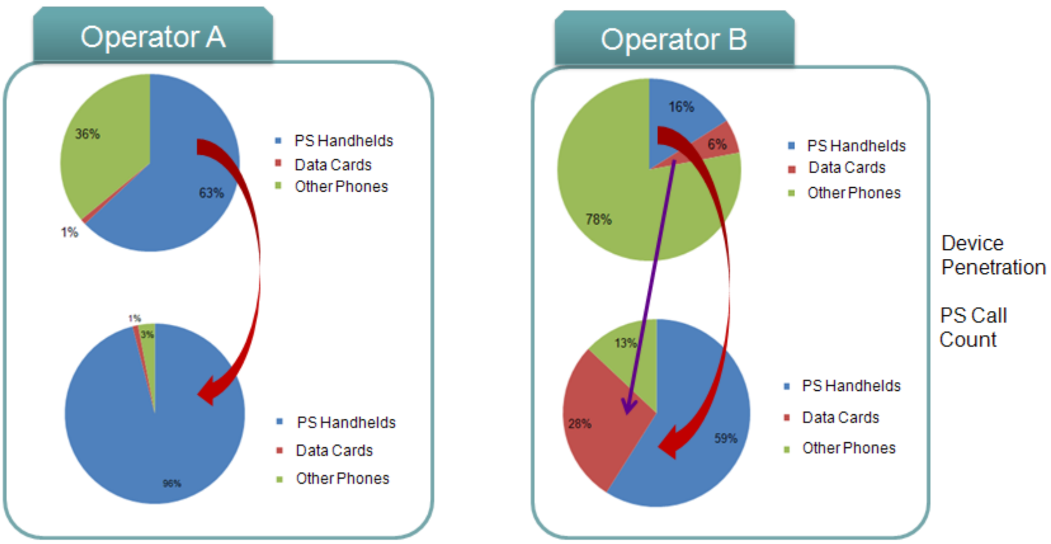

Figure C-2. Device Penetration & PS Call Count

Field data statistics

The following results represent statistics for all devices in the selected RNCs collected over a 24-hour period.

Distribution of PS Call Duration

Figure C-3 shows statistical distribution of duration of PS calls generated by data communication UEs. PS call is defined by signalling messages from RRC/RAB setup and PDP activation, until RRC release.

As expected, many PS calls are "short". Additionally, sharp peaks in call duration probability at around 8 seconds in both networks seems to suggest battery energy saving techniques as a likely cause. Battery energy saving technique refers to the behaviour of some pre-R8 terminals, which, upon completion of a data exchange procedure, would autonomously go into a dormant state, thus releasing the RRC connection. While this UE implementation-dependent (proprietary) action of autonomously entering dormancy is advantageous in terms of conserving UE battery power, it would tend to increase the network impact since it may result in additional signalling due to connection release, only to be followed up shortly thereafter by connection re-establishment, as user activity resumes.

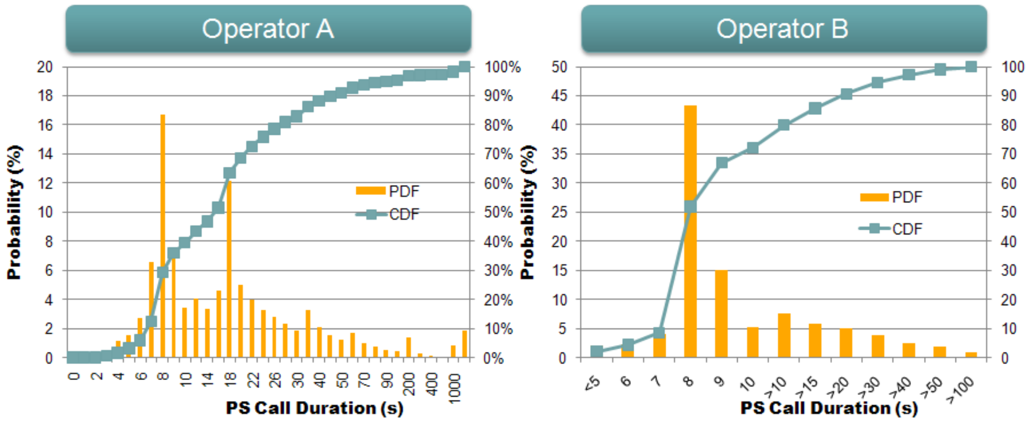

Figure C-3. Distribution of PS Call Duration

CDF: Cumulative Distribution Function

PDF: Probability Density Function

Data Volume of PS Calls

Figure C-4 shows distribution of data volume of PS calls. A large majority of calls is of very small volume: for both examples, a high percentage of calls transfer one kilobyte of data or less. This behaviour is typical of prevailing data applications such as push e-mail, social networking and instant messaging. Activities such as keep-alive messages, status reports, and polling contribute to such behaviour.

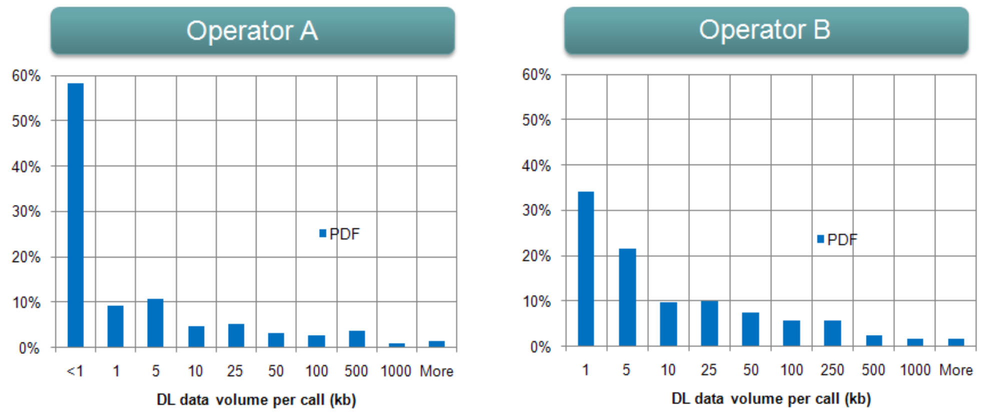

Figure C-4. Distribution of PS Call Volume

Note that the statistics shown are derived from several millions of PS calls taken over the two networks (one in Europe, another in North America) over several weekdays during March-May 2010 timeframe. Thus, the data represent a statistically significant sample for the timeframe in question.

Inter-arrival time of PS Calls

Figure C-5 shows distribution of inter-arrival times of PS Calls for a UE, compiled over many calls.

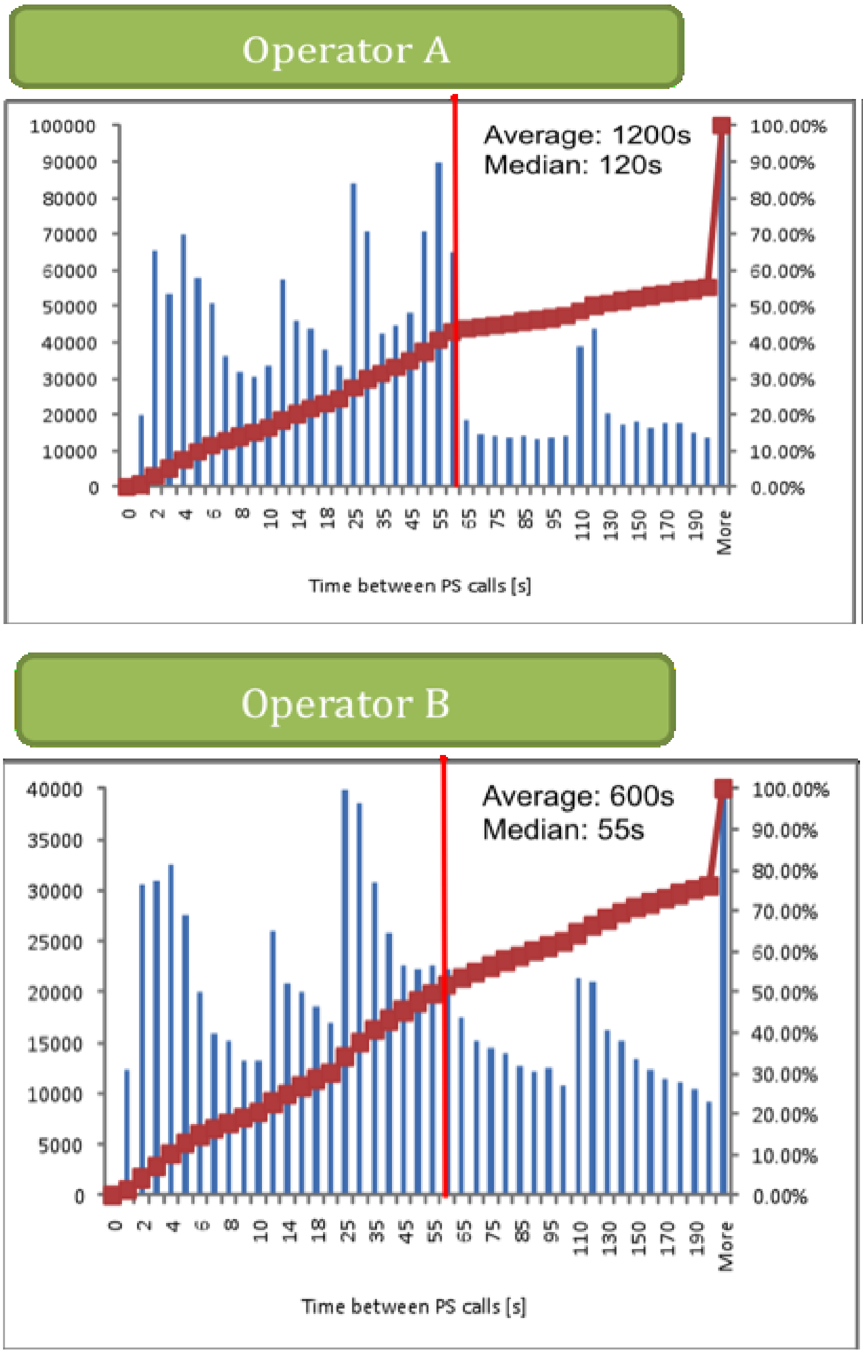

Figure C-5. Distribution of Inter-Arrival Time of PS Calls

The red curve shows CDF of call inter-arrival time (secondary y axis). The purpose of the vertical red line is to show that ~50% of calls occur within 60 seconds of the previous one. This reflects typical user behaviour of closely spaced data communication sessions when using a data communication device actively. The plot additionally shows how “chatty” data applications traffic is.

A recent presentation on “The Future of Mobile” provides some interesting insights into what is happening with smart phones and increasingly with 3G and LTE-equipped tablet computers. While looking somewhat more at the user behaviour side of the rapidly evolving situation, it provides strong evidence of the rapid rise in data traffic associated with very rapid shift to use of wirelessly networked smart phones and tablet computers vs. the declining use of fixed (desktop) personal computers, and hence the need for mobile network operators to find ways to manage this traffic effectively. [77]

16 Examples of Approaches to Dealing with M2M and Smart Phone Traffic

There are a number of potential solutions to the problems that network operators will be facing due to M2M and Smart Phone traffic.

M2M traffic will be present on mobile operator networks, its volume will grow very significantly in the next few years, and mechanisms to deal with M2M traffic are both possible and available. Additional methods are anticipated to be developed in the near future. Mobile network operators should plan early on to incorporate these capabilities into their networks and into their service offerings.

M2M traffic cannot be blocked in its entirety because it can be handled as data sessions and therefore is transparent to the network. Any M2M subscriber that is prepared to pay the fees set for access to data services and for the volume of data to be sent, can do so and obtain the services, given that the network has the capacity to support the service.

16.1 Good Citizen Approach

M2M Service Providers, as customers of mobile network operators, are interested in having their services work correctly and reliably. It is therefore in their interests to cooperate closely with their communications service providers to ensure this is the case.

When an M2M customer provides good forecasts of anticipated traffic levels and timings, the mobile operator is in a position to advise where problems may occur. By working together on timings, looking at mechanisms to distribute traffic, and what to do when the inevitable failure situations occur, it will be possible in many cases to have a win-win situation. A number of examples of how this cooperation can be realized are described in the following paragraphs.

Readings for natural gas and water meters can be scheduled for the early morning hours when other traffic is at a low point. Even then, care needs to be taken to that large batches of readings are not being sent simultaneously. A straightforward way of doing this is to set a defined time for a group of meters but have each meter use an offset from that time so that the load is distributed. If a group of one thousand meters provide readings beginning at 0300 local time, and each meter offsets its start of transmission by the number of seconds represented by the last three digits of its serial number, and given that the meter serial numbers have not been correlated in some way, then these meters will distribute their one thousand readings over a period of just under seventeen minutes.

As part of this approach, should there be a network failure or power failure, re-attempts will be deferred using suitable mechanisms to offset the attempt to access the network from the point in time when it becomes available again.

Manufacturers of M2M devices have indicted that implementation of suitable mechanisms to achieve this can be easily done.

16.2 Working with Application Implementers

When there are potentially many M2M service providers that will be using the same manufacturers products, it will be beneficial to work with the manufacturer directly rather than trying to negotiate with each of the M2M service providers.

As with the “good citizen” approach, it is in the manufacturer’s interest that its products work well and reliably. Through mutual cooperation with communications service providers, similar mechanisms to that described above can be worked out and agreed as a basis for implementation, especially where very large numbers of devices may be involved.

16.3 Tariff-Based

Most M2M customers will be seeking ways and means to minimize their communication costs consistent with the needs of their applications. In some cases such as critical health monitoring, intrusion alarm or environmental alarm conditions and the like, cost may not be a significant factor because of the importance of the event requiring M2M communication, or the relatively small number of such events, or the comparative cost of the event if nothing is done vs. the communication cost, or some combination of these factors.

In other cases, the number of instances of M2M communication will be high such as shown in Figure 10 - Forecast M2M Market Size in Japan and the cost of communication can become a significant factor in the viability of the M2M service. Low costs will be important. The M2M service provider can therefore be expected to approach the network operator with this in mind. This provides leverage for the network operator to steer the M2M customer towards operating its M2M services in such a way as to minimize the costs to the M2M subscriber while taking advantage of available capacity in the mobile operator's network.

Mechanisms that can be applied here are setting agreed time intervals when M2M devices may communicate at a low tariff, minimizing communication duration, i.e., release a data session as soon as the desired application data transfer has been completed. This approach can also be coupled with the "good citizen" and Application approaches described above.

16.4 Network-Based Mechanism: Extended Access Barring

While the above approaches can be effective in preventing many, indeed most, problems at the source, there will still be situations where they are inadequate. Sometimes an application will be poorly implemented and will not behave in such a way as to avoid causing difficulties for mobile networks. An individual device may fail in some way such that it repeatedly tries to access the network. An M2M service provider may simple purchase a large number of subscriptions without informing the network operator of the intended usage, leading to the possibility of significant periodic network loads such as shown in Figure 28 - Example of Periodic M2M Network Loading [53] Until the customer can be contacted and the situation remedies, it will be necessary to employ means included in the mobile network architecture and capabilities that it can use to protect itself.

A key method mobile networks use to protect themselves when congestion occur is called Access Class Barring. This is a mechanism that is invoked when congestion occurs whereby varying proportions of call attempts can be blocked to reduce the load on the network. The Access Barring values indicate which access class of user equipment it applies to, how long the barring period is, and what proportion of access attempts should be blocked. There is some variation by radio access network. Specific requirements are provided in section 4.3.1 of 3GPP TS 22.011 "Service accessibility" [78]. In section 4.3.2, the requirements for Service Specific Access Control (SSAC) in E-UTRAN are specified. SSAC is the application of independent access control for telephony services (MMTEL) for mobile originating session requests from idle-mode.

Extended Access Barring (EAB) was originally intended for M2M communications but was determined to be useful in a broader context. This is related to the point made in the Introduction to this technical paper on what a "user" is. The requirements for EAB are specified in section 4.3.4 of [78]. EAB is related to another concept from the work on M2M communication labelled low access priority. While there are discrete parameters related to EAB and low access priority, they are effectively one for Releases up to and including Release 11. There remains the possibility of finer control, in the future hence both parameters are being retained.

Extended Access Barring supplements Access Class Barring. That is, a user equipment configured for EAB shall use Access Class Barring if the network broadcasts that ACB information and the network is not broadcasting EAB information. If the network is broadcasting EAB information, a user equipment configured for EAB shall use it. This is intended to avoid adding load to the network from low priority M2M communications when high value communications can be supported but the network is at a point where additional load could lead to further congestion.

17 Offload Strategies

A method for reducing the data traffic load on a mobile network is to offload traffic to alternative access networks wherever possible. Candidate access networks include Wi-Fi, WiMAX, and fixed broadband networks.

In many cases of M2M communication, M2M device are fixed in position (e.g., utility meters, security system sensors, payment devices) or are stationary or nearly so (e.g., health monitoring, environmental sensors, etc.) Spectrum for PLMNs is a scarce resource, and depending on the local regulatory approach, can also be very expensive. Therefore, when practical it makes sense to move traffic away from it in favour of traffic that must be carried on the PLMN due the degree of mobility of the devices, or due to non-availability of alternate access resources. When an M2M device is sufficiently capable, it can detect alternate access networks and use policy and subscription information provided to it at initialization to select an appropriate access resource.

In many cases, human users accessing data services will be in one location during a data session since such usage tends to be rather more "nomadic" than voice service where the user is moving. That is, a human user will browse the Internet, download and read or compose and send email, or watch streaming video while tending to remain in one location. While this will not always be true (e.g., watching a streaming video while on public transit), it will apply in many cases (e.g., when at a coffee shop or a shopping center.)

Mobile network operator KDDI in Japan provides an excellent example of the application of this strategy. The following text as well as Figure 36 - KDDI 3M Strategy for Handling Large Volumes of Data Traffic are copied from their web site [79]:

Multi-Use

Regarding the content services it has provided mainly on mobile phones, KDDI's aim is services that can be used seamlessly in fixed and mobile environments on a variety of devices. KDDI will provide the open Internet experience and content applications that only it can.

Multi-Network

KDDI will combine its fixed networks such as FTTH and CATV with mobile networks such as 3G and WiMAX by using Wi-Fi. KDDI will thus accommodate skyrocketing traffic and create with low cost and high quality the richer social infrastructure of the future that harnesses ICT.

Multi-Device

Beginning with the dissemination of smartphones, user interfaces have made innovative advances through the adoption of touch panels and other technologies. KDDI is constructing a new business model that can handle diverse devices such as smartphones, tablet computers, and PCs.

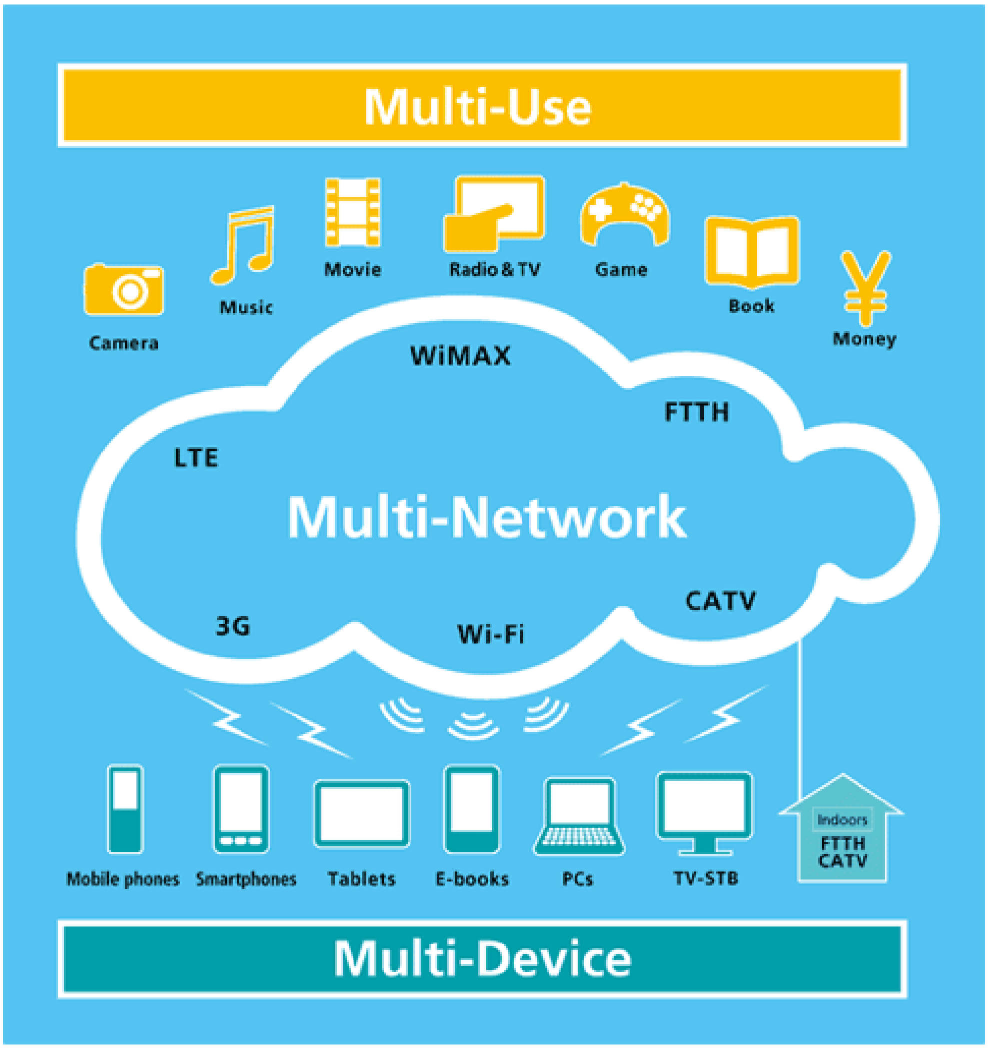

Figure 36 - KDDI 3M Strategy for Handling Large Volumes of Data Traffic

Recognizing that being able to offload the radio access network is a useful capability, 3GPP has worked, is working, or will work on a number of techniques that support this.

- QoS Control Based on Subscriber Spending Limits
- Service Awareness and Privacy Policies
- Usage Monitoring Control enhancement
- User Plane Congestion Management
- Local IP Access and Selected IP Traffic Offload
- Operator Policies for IP Interface Selection
- Location-Based Selection of Gateways for WLAN
- Multi Access PDN connectivity and IP flow Mobility
- Core Network Overload solutions
- Service and Media Reachability for Users over Restrictive Firewalls

17.1 QoS Control Based on Subscriber Spending Limits

While a mobile operator has several means to control subscribers' usage of the network resources, such as admission control policies[14], negotiation of QoS at session setup, etc., the operator needs to have a much finer granularity of control of the subscribers' usage of the network resources by linking the subscribers' session QoS with a spending limit. This gives the operator the ability to deny a subscriber access to particular services if the subscriber has reached the allocated spending

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[14] See sections on Access Class Baring and Extended Access Barring.

limit within a defined time period. At the same time, it should be possible to give the subscriber an opportunity to modify the session when this spending level is reached. This enables the subscriber to purchase additional resource credits if he so wishes. Also, this allows the operator to have an additional means of shaping the subscriber's traffic in order to avoid subscribers monopolizing network resources [80].

17.2 Service Awareness and Privacy Policies

Policy enhancements to the 3GPP architecture resulted in the conclusion that further standardisation is required in the area of Service Awareness and Privacy Policy. To facilitate this, a new entity known as a Traffic Detection Function (TDF) is defined for along with corresponding policy control signalling. The normative specifications, which handle Policy and Charging Control, were updated in order to cover the related architecture modifications [81].

17.3 Usage Monitoring and Control

Usage monitoring control was introduced into Policy and Charging Control in 3GPP Release 9. It provides operators with the capability to enforce dynamic policy decisions based on total network usage in real-time. It was enhanced under the Service Awareness and Privacy Policies work item in Release 11 to support usage monitoring for services that are detected by the TDF. Although deferred to beyond Release 11, this work item will look at:

- How one service/application can be included in more than one monitoring group;
- How a service data flow/application can be disabled from the existing usage monitoring group of services/group of applications;
- How to exclude the usage of a particular service data flow/application from the accumulated usage for the IP-CAN session/TDF session; and
- Operators may have different usage allowance for the same service data flow/application or IP-CAN/TDF session under different conditions, e.g., leisure and busy hour, or roaming and non-roaming. It is useful to optimize the procedure to reduce concurrent signalling caused by allowance changes due to these conditions, e.g., by keeping the accumulated usage value when the usage threshold is changed, but reporting it only when the next report is done to avoid many simultaneous reports.

Included is the capability to apply usage control for a subscriber group, e.g., the members of a family or the employees of a company, or for a group of devices belonging to a subscriber, that share the same usage allowance threshold [82]. Due to workload issues and prioritization, this work will be addressed beyond Release 11.

17.4 User Plane Congestion Management

Mobile operators are seeing significant increases in user data traffic. For some operators, user data traffic has more than doubled annually for several years. Although the data capacity of networks has increased significantly, the observed increase in user traffic continues to outpace the growth in capacity. This is resulting in increased network congestion and in degraded user service experience. Reasons for this growth in traffic are the rapidly increasing use of "smart phones" and the proliferation of data applications that they support and the use of USB modem dongles for laptops to provide mobile (or at least nomadic) Internet access using 3GPP networks. As the penetration of these terminals increases worldwide, this trend of rapidly increasing data traffic is expected to continue and accelerate.

The objective of this new work item agreed in 3GPP SA1 in November 2011 and anticipated to be approved by the 3GPP SA Plenary in December 2011 is to study scenarios and use cases where high usage levels lead to user plane traffic congestion in the RAN, and to propose requirements for handling user plane traffic when RAN congestion occurs. The aim is to make efficient use of available resources to increase the potential number of active users while maintaining the user experience [83].

17.5 Local IP Access and Selected IP Traffic Offload

Support of Local IP access (LIPA) for a Home (e)NodeB Subsystem and of Selected IP traffic offload (SIPTO) for the Home (e)NodeB Subsystem and for the macro layer network includes the following functionality:

- Local IP access to residential/corporate local network for the Home (e)NodeB Subsystem;
- Selected IP traffic offload (e.g., Internet traffic) for the Home (e)NodeB Subsystem; and
- Selected IP traffic offload (e.g., Internet traffic, corporate traffic) for the macro network (3G and LTE only.)

Also included are:

- The support of mobility for LIPA between the H(e)NBs located in the local IP network; and
- Functionality to support Selected IP Traffic Offload requirements at the local network, including mobility.

Related 3GPP documents are:

- TR 23.829 Local IP Access and Selected IP Traffic Offload (LIPA-SIPTO) – Release 10 [84]
- TR 23.859 LIPA Mobility and SIPTO at the Local Network – Release 11 [85]
- LIMONET Deprioritized SA2 - LIPA Mobility and SIPTO at the Local Network SP-100705 [86]

Due to workload issues and prioritization, work on LIMONET will be addressed beyond Release 11.

17.6 Operator Policies for IP Interface Selection

Selection across multiple IP interfaces is a generic problem of “multi-homed” terminals and applies to both physical interfaces (e.g., cellular vs. WLAN) and logical interfaces (e.g., selection among multiple PDN connections). 3GPP UEs supporting multiple PDN connections have had to deal with the problem of selecting the proper interface for routing IP flows since Release 99 in an implementation-specific ways.

The 3GPP Release 10 architecture allows the operator to dynamically or statically configure the UE with inter-system routing policies that assist a dual-radio UE in selecting an IP interface on a per-flow basis: the inter-system routing policies allow the UE to identify traffic flows that can be offloaded non-seamlessly via the local address assigned on the WLAN interface.

With EPS, usage of simultaneous PDN connections will become common and the UE will have several options for routing of certain traffic flows. For example, Internet-bound traffic flows could be routed via multiple available interfaces. Release 10 inter-system routing policies allow operators to influence UEs to select between 3GPP access or non-seamless WLAN offload, but do not allow operators to influence UEs to select a specific interface among the available interfaces for routing of IP flows.

In Release 11, a new requirement for Selected IP Traffic Offload (SIPTO) via the Home (e)NodeB subsystem defines SIPTO policies per APN, per IP flow class under any APN, or per IP flow class under a specific APN. This work aims to enhance operator policies for IP interface selection to route specific IP flows.

While this work addresses moving traffic to selected access resources based on operator policies, it does not include consideration of the congestion status of the access network other than at the considerable distance of setting the policies based on experience [87].

17.7 Location-Based Selection of Gateways for WLAN

WLAN Access to EPC with IP address continuity was \defined in Release 8 and extended in Release 10 with IP Flow mobility (IFOM) and MAPCON. This work item adds consideration of the UE's location as well as its proximity to the PDN GW to optimize routing from the UE to the ePDG. Similarly, PDN GW selection in S2b and S2c cases did not consider the UE's location, so this work item will improve ePDG and PDN-GW selection based on the UE's location for WLAN Access to EPC in these cases [[88]]. Due to workload issues and prioritization, this work will be addressed beyond Release 11.

17.8 Multi Access PDN Connectivity and IP flow Mobility

Dual radio devices (e.g., 3GPP/LTE –Wi-Fi) are becoming commonly available and the set of applications running in these mobile devices is diversifying. While some applications are well suited to running over 3GPP access systems, other applications may be well suited to running over other complementary access systems (e.g., ftp transfer via Wi-Fi in parallel to VoIP over LTE.) In some environments (e.g., at home, in the office, on campus) it may be desirable to take advantage of the capability of dual-radio devices to be connected to two different access systems simultaneously.

Release 8 EPS introduced a multi access 3GPP system where different heterogeneous access systems (e.g. 3GPP, 3GPP2, Wi-Fi, WiMAX, fixed broadband access, etc.) are connected to a common EPC. In the EPS the subscriber can connect to the same PDN via any of the available access systems, however it is not possible to connect to the same PDN simultaneously via different accesses. The same limitations apply to release 8 I-WLAN mobility.

In Release 8 EPS, there is no means in 3GPP to dynamically direct individual IP flows generated by different applications and belonging to the same PDN connection to specific access systems. This capability can be achieved by introducing IP flow mobility to allow dynamic allocation of different IP flows to different access systems so that the user experience can be enhanced while the connectivity cost for the operator can be optimized.

In Release, a UE can connect to one PDN over a 3GPP access system and a second PDN over a different access system, however handovers between the access systems in such scenario are not described [89]. Due to workload issues and prioritization, this work will be addressed beyond Release 11.

17.9 Core Network Overload Solutions

In reviewing an incident in a network which resulted in "HLR Overload" (i.e., the HLR received queries at the rate of 600% of engineered capacity), it was found that the specific cause of this incident was a restart of a Radio Network Controller (RNC) that removed the control channel. This forced all the mobiles in a large area to reregister. Once this surge of traffic started, the HLR was not able to complete the registration before some newer handsets ("smart phones") timed out their registration attempt and so restarted the entire registration process on all networks (2G and 3G, voice and data) to which they were already attached. This created even more traffic. Once the delay at the HLR exceeded the UE timeout value, all of these "smart phones" were unable to complete registration regardless of location. This situation was manually resolved by drastically reducing the HLR queue (e.g., by shutting down links) to break the cycle by reducing the delay at the expense of discarding a large number of messages, and the network recovered [90].

Increases in signalling speed and the concentration of subscribers into fewer HLR nodes create an environment in which situations can change quickly. Since more subscribers are supported per HLR, more subscribers may be impacted when there is an HLR problem. The HLR is a not a unique network element in this regard. Similar scenarios might occur as well to other "core" network elements as the behaviour of the UE becomes increasing complex. This aspect though needs further investigation.

In response to this situation, there is a study on how the RAN response to failure might be changed to avoid spikes in demand on core network nodes, on whether core network nodes might notify the rest of the network if they are entering overload, and what the other corer network nodes might do in such cases.

While the particular instance described was due to "smart phone," the study is also considering what might happen in a node restoration instance where there are large numbers of M2M devices involved [91]. Due to workload issues and prioritization, this work will be addressed beyond Release 11.

17.10 Service and Media Reachability for Users over Restrictive Firewalls

Mobile operators may provide both IMS and non-IMS services that may be accessed via different access technologies and not exclusively by cellular access technologies. This presents a new challenge in that some access networks not affiliated with the mobile operator may have implemented firewalls that block access to some operator services.

The IMS service requirements (TS 22.228 [92]) have been extended to cover new requirements for IMS firewall traversal.

Industry has historically adopted proprietary approaches to traverse such firewalls. One example approach is to tunnel application traffic over TLS/TCP on HTTPS's well-known port number, emulating HTTPS web traffic. Such solutions have worked reasonably well, but a standard for such secure access is needed to enable multiple UE and access gateway vendors to be used.

While 3GPP has specified some mechanisms to handle NAT and firewall traversal for IMS based on tunnelling techniques, there is a need to review the existing mechanisms to assess whether these are suitable or if other mechanism are needed.

The objectives of this work item [93] are:

- To specify the requirements that can facilitate UE access to the PLMN IP-based services over restrictive firewalls that only allow Internet traffic using HTTP (with and without security) in non-3GPP access networks.
- The scope excludes:
  - the use of the solution for H(e)NB connectivity to the mobile operator's network
  - NAT traversal

18 M2M Standards

There is a significant amount of standards work on-going that deals with M2M Communications. ITU-T work in this area is summarized in Annex A which focuses on a Joint Coordination Activity on the Internet of Things (JCA-IoT.)

The 3GPP and 3GPP2 Partnership Projects are the most active in this area, along with their Organizational partners. Figure 37 illustrates the membership of the 3G Partnership Projects.

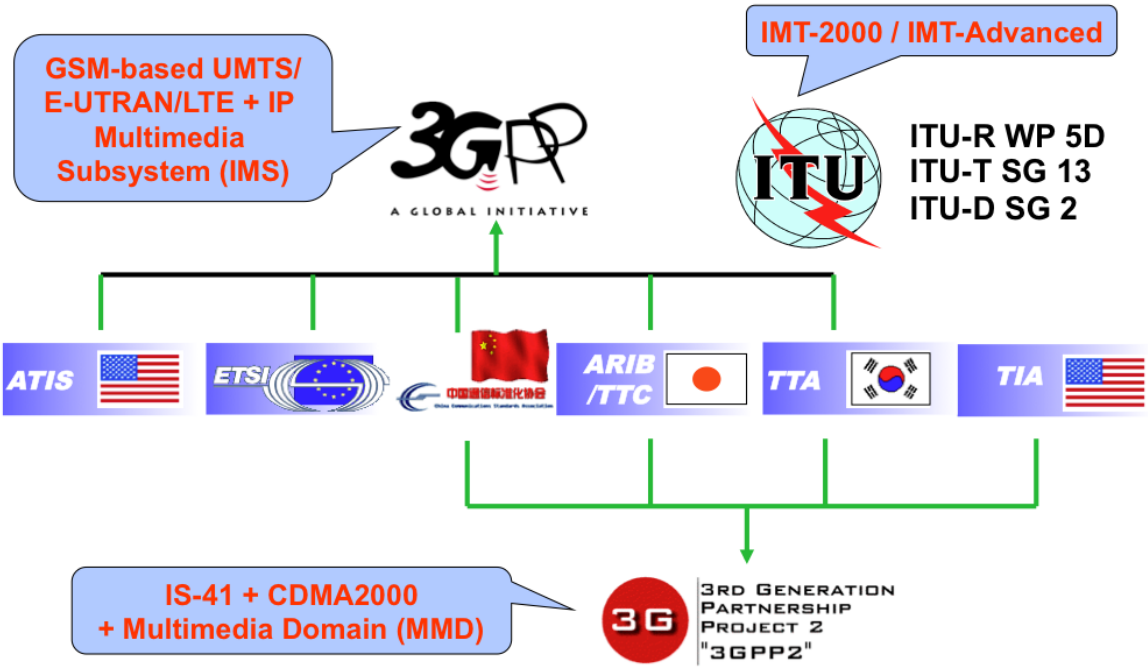

Figure 37 - 3GPP, 3GPP2 and ITU Mobile Standardization

3GPP publishes regular updates on its work in this area, along with the work done in its Organizational Partners. The main focus of that document is on the M2M Communications work items in 3GPP and ETSI, but it includes sections on the work underway in the other Organizational Partners based on information they provide.

Rather than try to provide all these details in this technical paper, it is more useful to provide a link to the 3GPP web site where the current version may be obtained. As this is written, the current version is dated 24 January 2012 and is available at [94]. Look for the filename beginning with "M2M... ." Previous versions of this document are also available at the same location in a directory labelled "Previous_versions."

Annex B provides the current version's Table of Contents as an indication of the range of studies underway.

3GPP2 is less active than 3GPP in this area but still does important work. The following documents are relevant and useful:

- SC.R4005-0 v1.0 "cdma2000 M2M Numbering Recommendations System Requirements Document" deals directly with numbering and related aspects for M2M Devices [[95]]
- SC.R5003-0 Version 2.0 24 June 2010 "GPP2 Vision for 2010 and Beyond" includes a substantial section on M2M [96]

18.1 ITU-R Work on Wide Area Sensor Networks

ITU-R's "Wide Area Sensor Networks" essentially deals with M2M communications.

In a liaison to 3GPP (Document 5A/TEMP/337(Rev.1), ITU-T Study Group 5 provided the current situation on its work [97].

ITU-R Working Party 5A is working on "Mobile wireless access systems providing telecommunications for a large number of ubiquitous sensors and/or actuators scattered over wide areas in the land mobile service", under Study Group 5 Question ITU-R 250/5. This includes aspects of machine-to-machine (M2M) communications that your group may also be working on, or your systems/standards may be able to support.

WP 5A completed its work on two documents at the meeting (8-17 November 2011) for submission to the Study Group 5 meeting (21-23 November 2011) for approval.

These documents are attached for information (see Attachment 1 and Attachment 2).

WP 5A thanks the external organizations which contributed to this work via liaison statements.

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Attachment 1: Draft New Recommendation – "Objectives, characteristics and functional requirements of wide-area sensor and/or actuator network (WASN) systems"

Attachment 2: Draft New Report – "System design guidelines for wide area sensor and/or actuator network (WASN) systems"

NOTE - Both of the attachments referenced in the liaison were revised on 1 December 2012 and access to the revised attachments require an ITU TIES account.

The essential content of the version of Attachment 1 provided with the above liaison is copied here. The content will be very familiar to anyone working on M2M.

1 Introduction

This Annex provides the objectives for wide-area sensor and/or actuator network (WASN) systems, in this Recommendation for communications to a large number of sensors and/or actuators.

2 Objectives

2.1 Support of M2M service applications

The mobile wireless access system should support a variety of machine-to-machine (M2M) service applications such as automation and efficiency enhancement of business works, environment observation, remote control of plant facilities, social security and the reduction of environmental impact, irrespective of their locations.

2.2 Coverage of a wide range of sensor and/or actuator densities

The mobile wireless access system should provide these services over a wide range of sensor and/or actuator densities, irrespective of whether service areas are inhabited or uninhabited.

2.3 Accommodation of a large number of sensors and/or actuators

The mobile wireless access system should accommodate a large number of sensors and/or actuators and provide services at an acceptable cost. For some applications, the number of sensors and/or actuators could be several times the population.

The wireless access system used for sensor and/or actuator communications should support a large address space to accommodate a large number of sensor and/or actuator devices.

2.4 Easy system installation and simple deployment

The mobile wireless access system should provide both easy system installation and simple deployment which reduce the number of base stations (BSs).

This objective enables the operator to easily provide M2M service applications on a cell-basis.

2.5 Power efficient system

The mobile wireless access system should use power efficiently to ensure longer battery life of the wireless sensors and/or actuators and to minimize the environmental impact. In particular, the wireless sensors and/or actuators could be equipped with intelligent power saver algorithms and efficient sleep-wake cycle.

There are a great many wireless terminals (WTs) attached to sensors and/or actuators in a BS, so the enhancement of power efficiency per WT leads to a reduction in overall system energy consumption. This contributes to reduce the maintenance cost and environmental impact of the system, e.g., reduction of battery replacement cost and CO_2 emission.

2.6 QoS support

The mobile wireless access system should provide these services with a quality of service (QoS) performance equivalent to the QoS of the public mobile networks.

Since service applications may have different QoS, e.g. reliability, latency, data accuracy, it is important to support a broad range of QoS.

2.7 Security

The mobile wireless access system should provide these services with security features equivalent to those available for data communication services on the public mobile networks.

Since information from sensors and toward actuators may include private information and confidential business information, it is important to protect this information from unauthorized and malicious outsiders.

2.8 Providing sustainable M2M services

The mobile wireless access system should provide sustainable M2M services which can apply upcoming innovative technologies and incorporate their future applications.

This objective enables to enhance the conventional service applications by introducing new technologies and incorporating the future extensions while supporting the conventional service applications.

2.9 Support of nomadic and fixed services

The mobile wireless access system should support nomadic and fixed M2M services as well as mobile M2M services.

2.10 Wireless terminal consideration

The mobile wireless access system should support a variety of sensors and/or actuators, regardless of their size, shape and materials, which are maintenance-free or requiring minimum maintenance, and can be installed even in harsh conditions (e.g., extreme temperatures and humidity, etc.).

The Introduction to the version of Attachment 2 included with the above liaison is reproduced below. That Attachment similarly provides content that is similar to the work being carried out in 3GPP, ETSI, etc.

1 Introduction

There is a growing need to provide wireless access media that can link sensors and actuators associated with humans or widely-dispersed objects to core networks in order to support an increasing number of popular service applications. Mobile wireless access systems are in demand for a variety of services such as environment monitoring, stolen goods tracing, monitoring of gas, water, and electricity use for reducing environmental loads, social security and health care, etc.

The mobile wireless access system is a large cell-based public network that can provide telecommunications to various objects including machine-to-machine services with wide area coverage. A large cell-based wireless access system with a cell radius of about several to ten km is especially practical in supporting rural and non-residential areas as well as urban or residential areas owing to its simple and cost-effective cell deployment.

Research and development activities are making significant progress on mobile wireless access systems, and standardization is now a key issue. From these viewpoints, it is important to share a variety of information. This Report provides detailed information for system design policy, the wireless applications and examples of wide area sensors and/or actuators network (WASN) systems for information sharing.

19 Conclusions

The nature of M2M applications is such that their requirements differ considerably.

The market for M2M communication is expected to grow very rapidly, moving from proprietary solutions driven by regulatory requirements, which will enable wide adoption of low cost systems.

The evolution of computing technology has enabled the evolution of user equipment to smart phones which are in fact general purpose computing platforms with computing power, speed and capacity far in excess of desktop computers of only a few years ago.

The nature of smart phone applications, similarly to that for M2M, is such that their requirements differ considerably.

The market for applications that can be installed on smart phones is enormous as demonstrated by Apple's iOS Apps and Android's Apps Marketplace. The classifications of applications in these two primary application resource bases is somewhat different but the differences do not change the fundamentals of what these multitudes of applications require with respect to processing power, memory, and especially communications capabilities.

The demands of M2M Communications and of Smart Phones on the data networks they are connected to are rapidly consuming the capacity of those networks. Application behaviour that have strong implications for mobile networks include:

- Frequent idle-active mode transitions
- Frequent live updates (mobile originated and terminated ("push services"))
- Periodic keep alive messaging (mobile originated and terminated)
- Frequent start and stop of services
- Frequent small data transmission
- Bursts of data services resulting in deliberate or accidental denial of service
- Large downloads of data and media files, software updates and similar items

There are techniques for managing this today, and many further techniques for dealing with this rapidly growing area are being developed. Some of the techniques already available or soon to be available are:

- QoS Control Based on Subscriber Spending Limits
- Service Awareness and Privacy Policies
- Usage Monitoring and Control
- User Plane Congestion Management
- Local IP Access and Selected IP Traffic Offload
- Operator Policies for IP Interface Selection
- Location-Based Selection of Gateways for WLAN
- Multi Access PDN Connectivity and IP flow Mobility
- Core Network Overload Solutions
- Service and Media Reachability for Users over Restrictive Firewalls

The standards for M2M are progressing well but will still take a little time to mature to the point where they will enable the third wave of M2M and smart phone applications to take advantage of standardized vs. proprietary solutions.

Annex A:

ITU-T and M2M Studies and Standards

ITU has done considerable work in exploring the "Internet of Things" and has published a comprehensive report with this title. [98]

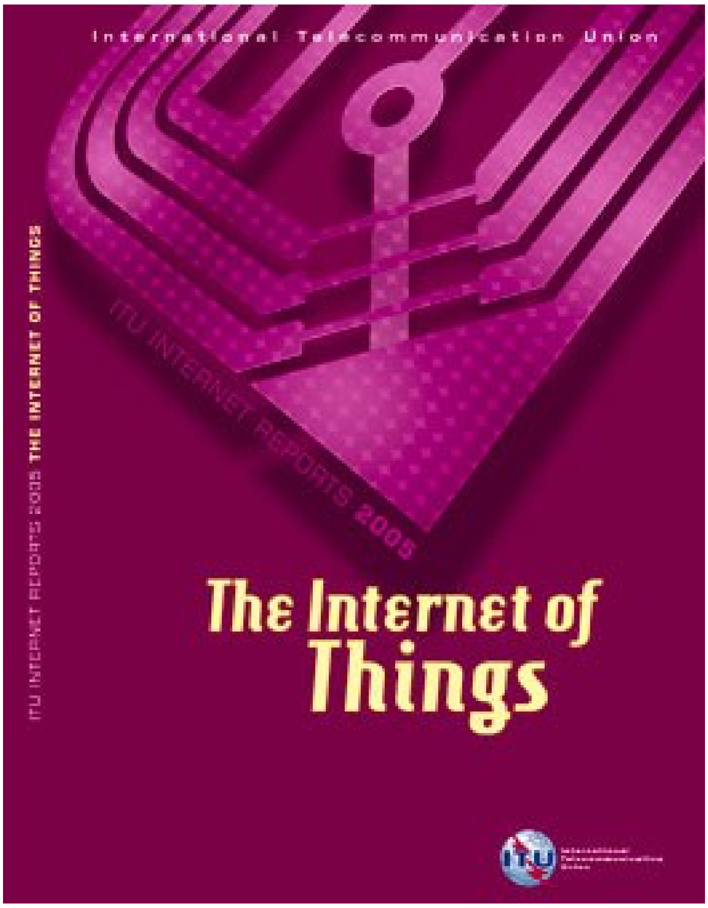

Figure 38 - ITU Internet Reports 2005: The Internet of Things

This was followed by the establishment of the Joint Coordination Activity on Internet of Things (JCA-IoT), approved by ITU-T TSAG in February 2011. The Scope and Terms of Reference as well as links to documents from past meetings and information on future meetings are available from the ITU-T web site. [99] Of particular relevance is an "IoT Standards Roadmap" as of November 2011. [100]

Further to this road map, ITU-T SG 16 has provided an update to the JCA IoT as of December 2011, as an input to the meeting of the JCA IoT in February 2012. [101]

Both of the above documents may be readily obtained from the ITU eb site by using the indicated links.

Annex B:

3GPP, 3GPP2 and their OP SDOs' Standardization of Machine-type Communications

This Annex refers to 3GPP, 3GPP2 and the SDOs that are Organizational Partners (OPs) in 3GPP and 3GPP2, hence not all organizations involved in M2M are covered. The information that follows represents the information available as of the January 2012 and is not exhaustive.

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References and Bibliography

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