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Quality of Service in Wireless IP Networks: Trends & Challenges

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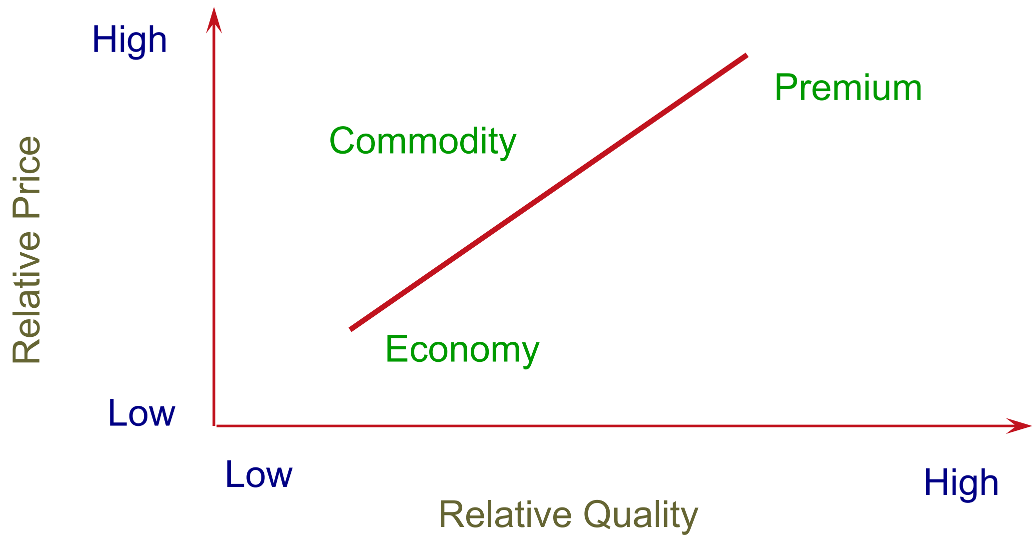
What is QoS?

Quality isn't free

- Strong coupling between quality and price

value = function (benefits(quality), and price)



- For network and service providers, quality improvement is achieved by spending more "Resources"

Network Resources

- Things a network "spends" to support traffic
- Mainly:
  - Bandwidth
  - buffers
  - Processors
- May be used "on-the-fly", or reserved in advance

Competing Objectives

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- Better QoS and efficient resource utilisation are competing objectives
- I can easily give you more QoS by spending more resources
- I can easily utilise resources more efficiently by giving you less QoS
- Traffic Management is about getting good QoS and good resource utilisation at the same time

This is Good News !

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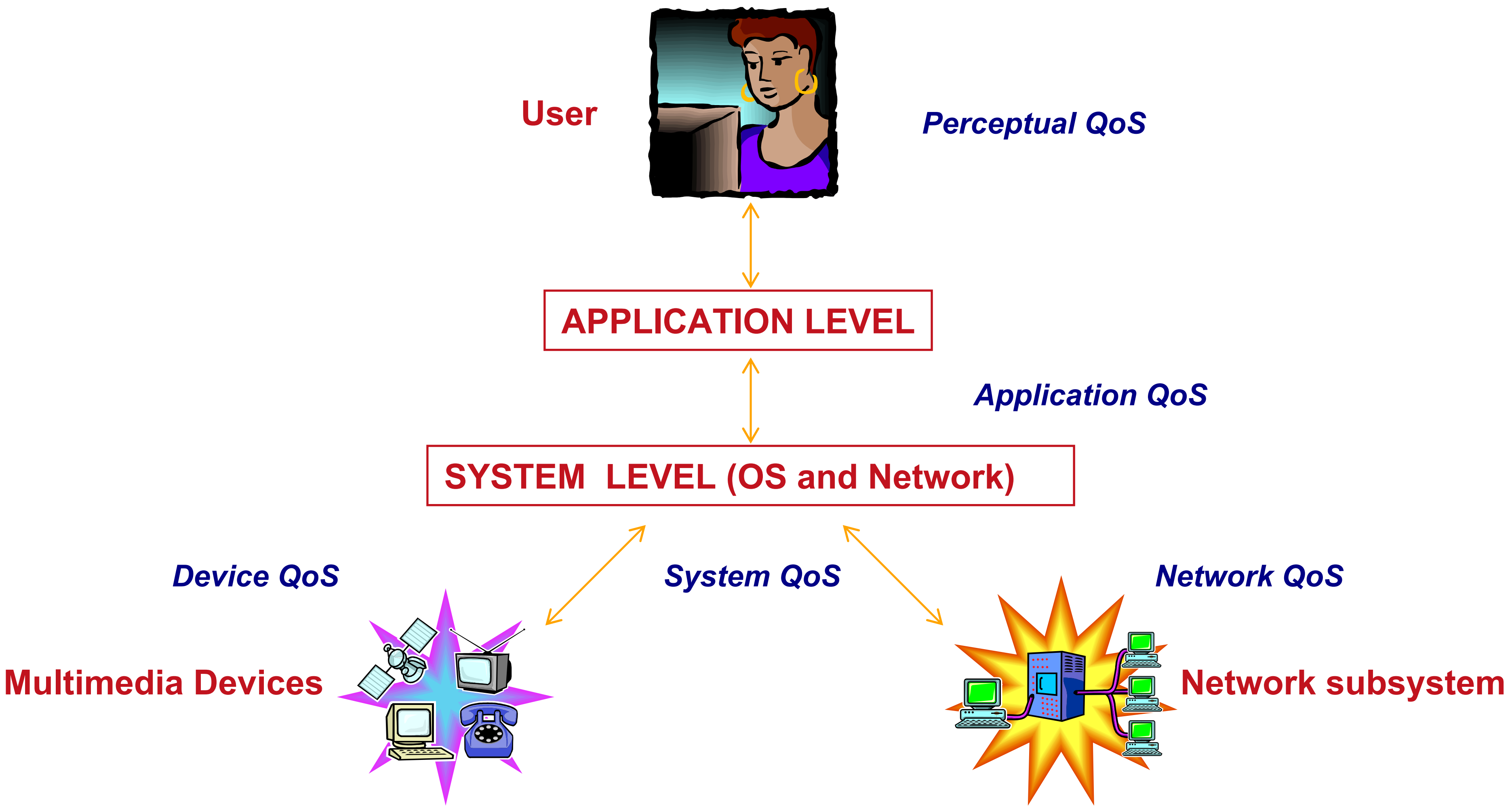
- Making intelligent trade-offs is what engineers do
- The stakes are high (€€€)
- Therefore the Traffic Management problem makes for high paying engineering jobs!

- At least it used to!

QoS Framework



Translation of QoS Parameters

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Perceptual Parameter	*System Parameter*
Picture detail	Pixel resolution
Picture colour accuracy	Maps-to-colour information per pixel
Video rate	Maps-to-frame rate
Video Smoothness	Maps-to-frame rate jitter
Audio Quality	Audio-sampling rate and number of bits
Audio-Video synchronization	Video and Audio stream synchronised (e.g. lip- sync)

Source: M.Sloman & D Chalmers, "A Survey of quality of Service in mobile computing environments", *IEEE Communications Surveys*, pp2-10, 1999

Network QoS Parameters

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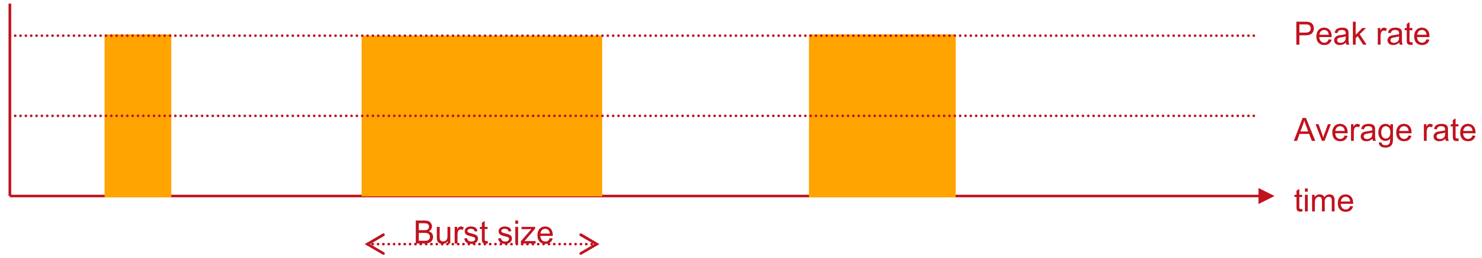
Category	*Parameters*
Timeliness	Delay Response time Jitter
Bandwidth	Systems-level data rate Application-level data rate Transaction rate
Reliability	Mean time to failure (MTTF) Mean time to repair (MTTR) Mean time between failures (MTBF) Percentage of time available Packet/cell loss rate Bit error rate (BER)

Source: M.Sloman & D Chalmers, "A Survey of quality of Service in mobile computing environments", *IEEE Communications Surveys*, pp2-10, 1999

Traffic Description

- **Types of Traffic Sources**
  - Constant Bit Rate (**CBR**)
  - Variable Bit Rate (**VBR**)
- **Traffic Parameters**
  - **Peak Rate** is the maximum data rate in any time interval
  - **Average Rate** is the "long term" mean of the traffic for a VBR source
  - **Burst Size** is the number of packets that can be transmitted at the peak rate.



QoS parameters of Typical Internet Traffic

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Applications Requirements	Maximum Delay(s)	Maximum Delay Jitter (ms)	Average Throughput (Mbit/s)	Acceptable Bit Error Rate	Acceptable Packet Error Rate
Audio (Telephone Quality)	0.25	10	0.064	$< 10^{-1}$	$< 10^{-1}$
Uncompressed Video (TV Quality)	0.25	10	100	10^{-2}	10^{-3}
Compressed Video	0.25	1	2^{-10}	10^{-6}	10^{-9}
Data (File Transfer)	1	-	2^{-100}	0	0
Real-time Data	0.001 – 1	-	< 10	0	0
Image	1	-	2^{-10}	10^{-4}	10^{9}

Internet QoS Mechanisms

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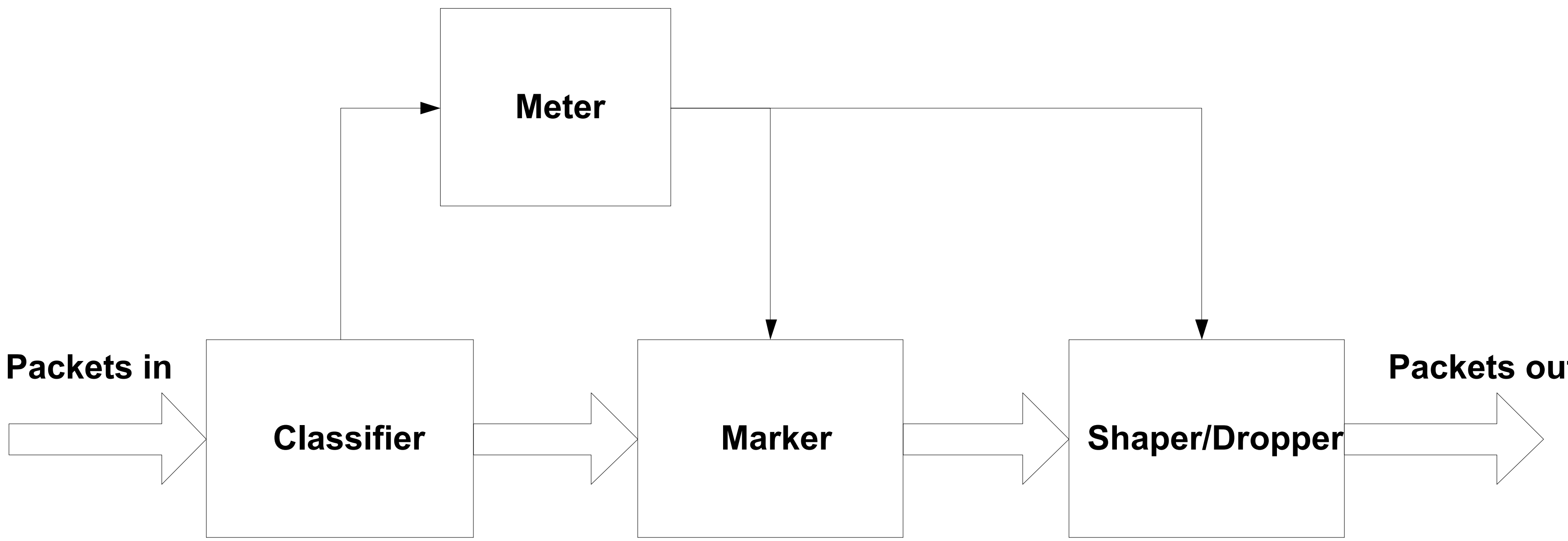
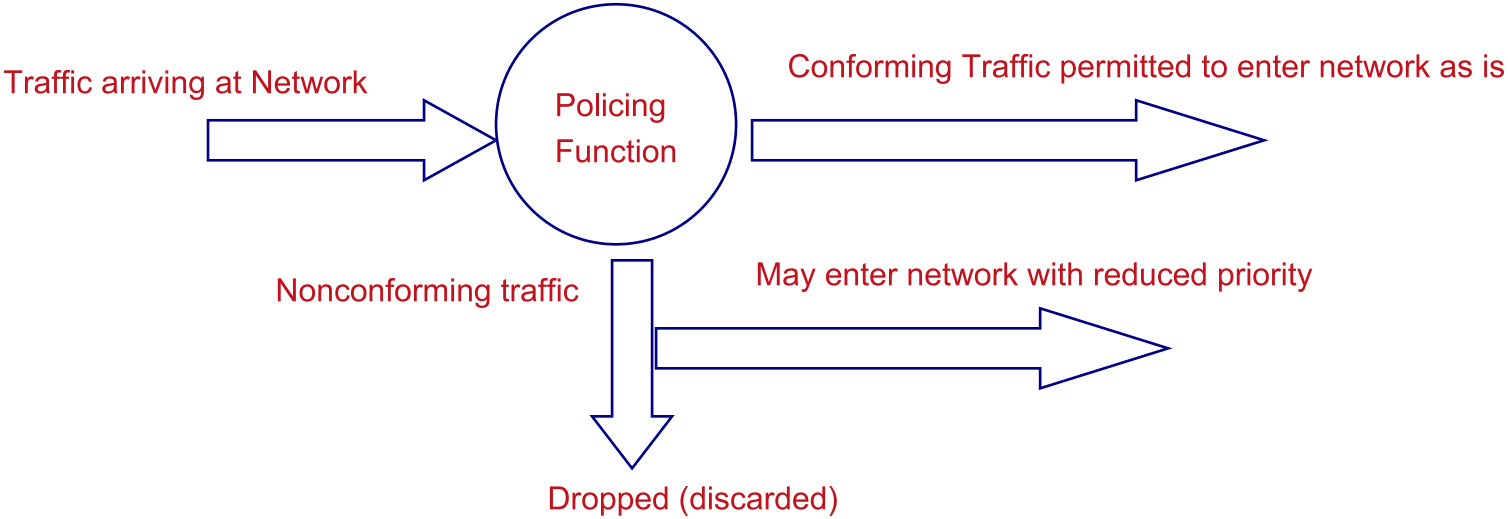
- ❑ Best Effort
  - No notion of QoS
- ❑ Integrated Services Model (IntServ)
  - RSVP
  - QoS defined on a 'per connection basis
  - Soft State – Doesn't scale to large networks
- ❑ Differentiated Services Model (Diffserv)
  - Centrally managed (per class, CBQ)
  - Simple and Efficient Implementation
  - Granular QoS
  - Dynamic change of QoS is not possible

Diffserv
Classifier & Conditioner



Traffic Policing

- All traffic entering a QoS network needs to be "policed" to ensure that it does not violate the "QoS contract", and thus cause disruption to other (well behaved) traffic.
  - The policing is performed on every packet entering the network.



Traffic Policing

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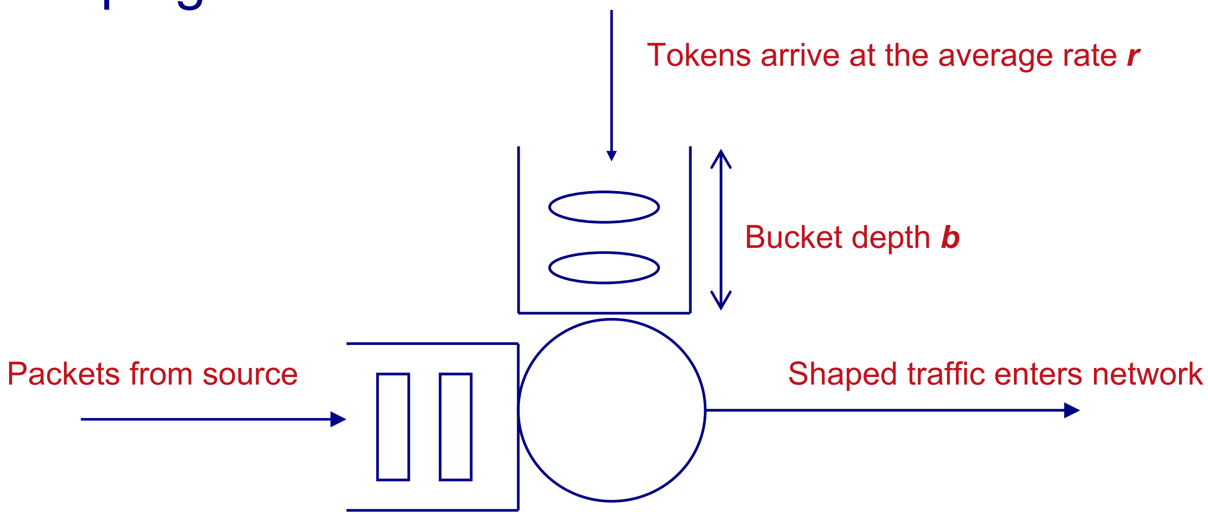
- **Requirements for Traffic Policing:**
  - It must not discard or decrease the priority of packets that do not violate the negotiated contract
  - It must detect every packet that violates the contract and take appropriate action (drop or reduce priority)
  - It should operate in real-time and should not cause any additional delay for the admitted packets
  - It should not be too complex to implement

- **Policing Parameters:**
  - Traffic is policed on various combinations of the basic descriptive parameters (peak, average rate, burst size)

Traffic Shaping

- Shaping is used to control the shape of traffic so that it does not violate any of the traffic parameters. It is generally employed at the source
- Shaping is very similar to Policing, except that shapers do not discard violating traffic. They store traffic in buffers to smooth out bursts.
- Traffic shapers can use leaky and token buckets to smooth traffic:
  - Average rate and burst size shaping
  - Peak rate shaping.



Queuing and Scheduling

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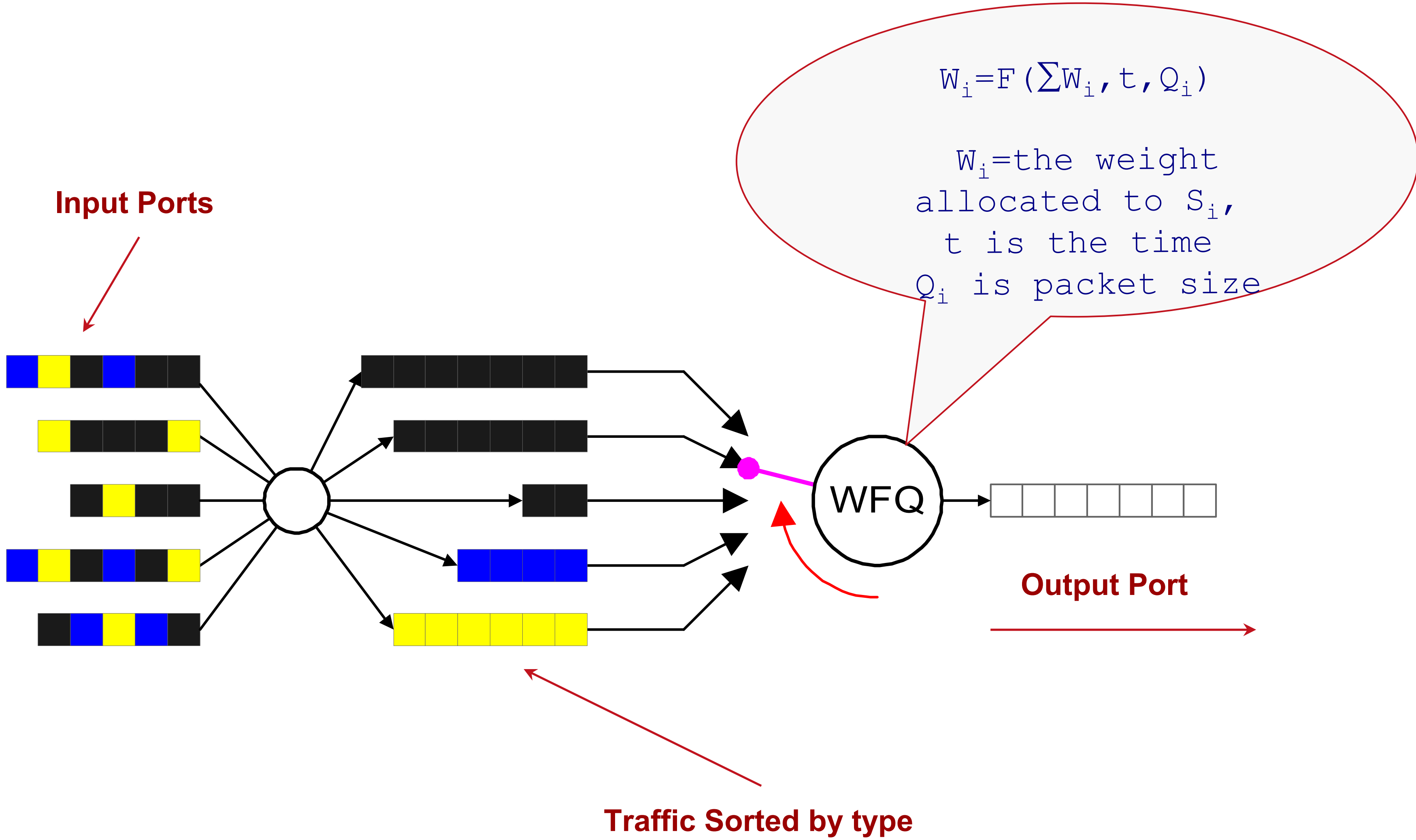
- Used to share link bandwidth in packet switched networks
- **Queuing** refers to the process of buffering incoming packets to a communications link
- A **Scheduling algorithm** defines the transmission sequence of packets over the link.
- Packet loss rate, packet delay and other QoS parameters of a given traffic flow can be significantly affected by the choice of queuing and scheduling techniques.
- Scheduling of resources such as link bandwidth is key to providing performance guarantees to applications that require QoS

Packet Scheduling



Quality of Service (QoS)

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QoS in Wireless IP networks

Packet Scheduling for Wireless

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Providing QoS in Wireless Links is Much Harder…

- Distributed
  - tied to the multiple access problem
- User mobility
  - makes resource reservation hard
- Channel errors
  - make resource reservation meaningless (no guarantees!)
  - make packet scheduling and fair resource allocation hard
    - what does fair mean in an error prone channel?
- Time varying channel

Problems with FIFO Scheduling in MACs [Bhagwat96]

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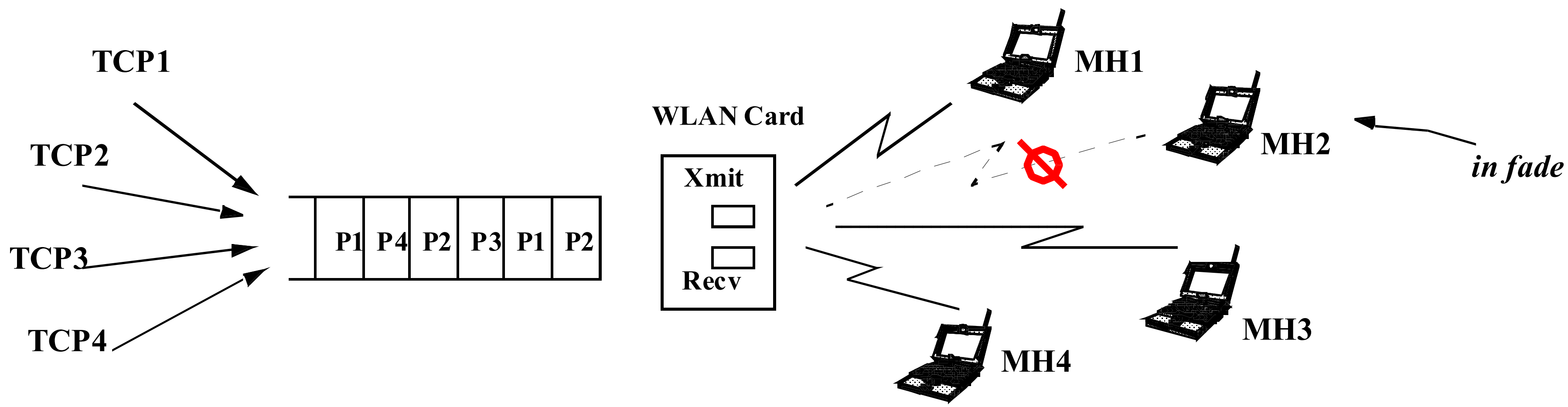
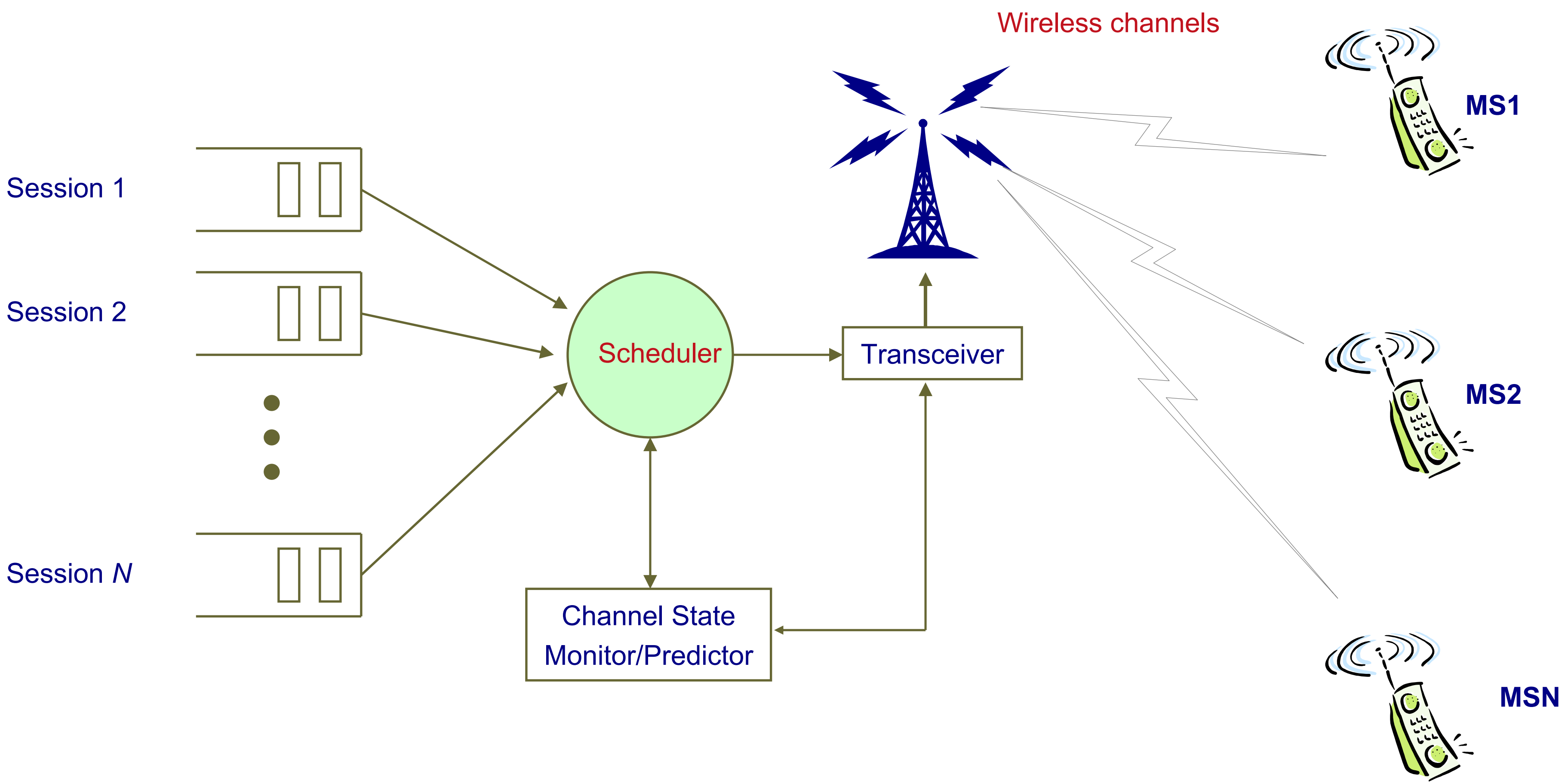


- **Burst errors may be spatially selective**
  - e.g. link to only one receiver may be under interference or in fade
- **During burst, all retransmission attempts to specific MH will fail**
  - burst errors observed to be 50-100 ms long in WLANs
- **FIFO is basically causing head of line blocking!**
  - other MHs starve even though link to them may be good
  - TCP's RTT estimates to all MHs will increase, further increasing timeouts
  - poor resource utilization
  - fairness problem: MHs with bad link claiming more link time & b/w
    - a "fair" MAC is not enough in the presence of errors on the link

A typical wireless scheduler

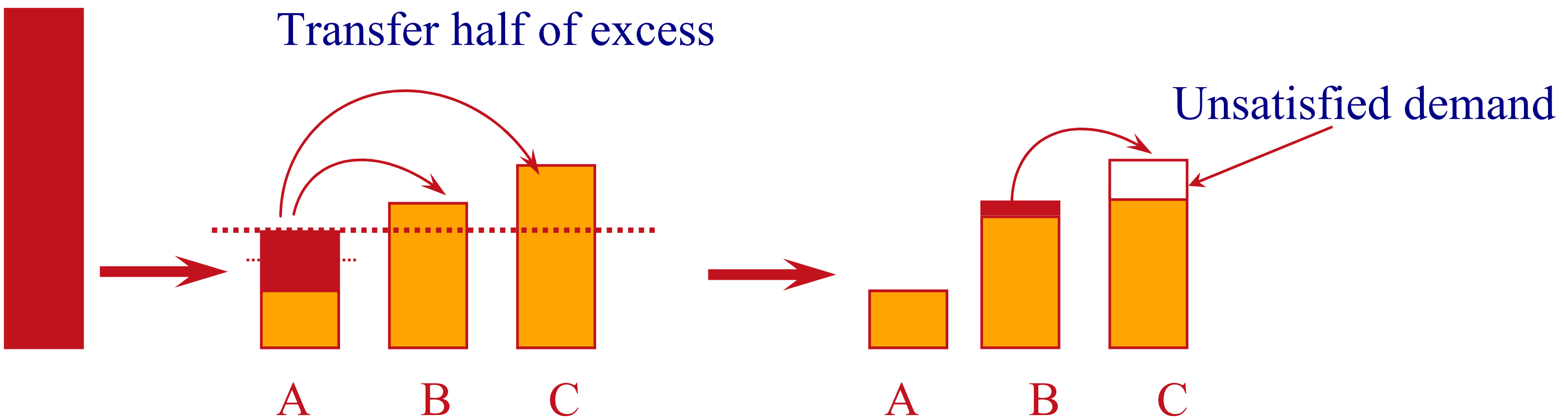


Wireless Scheduler components

- **error-free service model**
  - describes how the algorithm provides service to sessions with error-free channels
- **lead/Lag counter for each session**
  - Compares sessions with the error-free model
- **compensation model**
  - used to improve fairness among sessions
- **Separate slot and packet queues for each session**
  - can be used to support both delay-sensitive and error-sensitive sessions.
- A means for **monitoring and predicting the channel state** for every backlogged session

Fairness

- Intuitively
  - each connection gets no more than what it wants
  - the excess, if any, is equally shared
- Fairness is *intuitively* a good idea
- Fairness also provides *protection*
  - traffic hogs cannot overrun others
  - automatically builds *firewalls* around heavy users



Power Considerations

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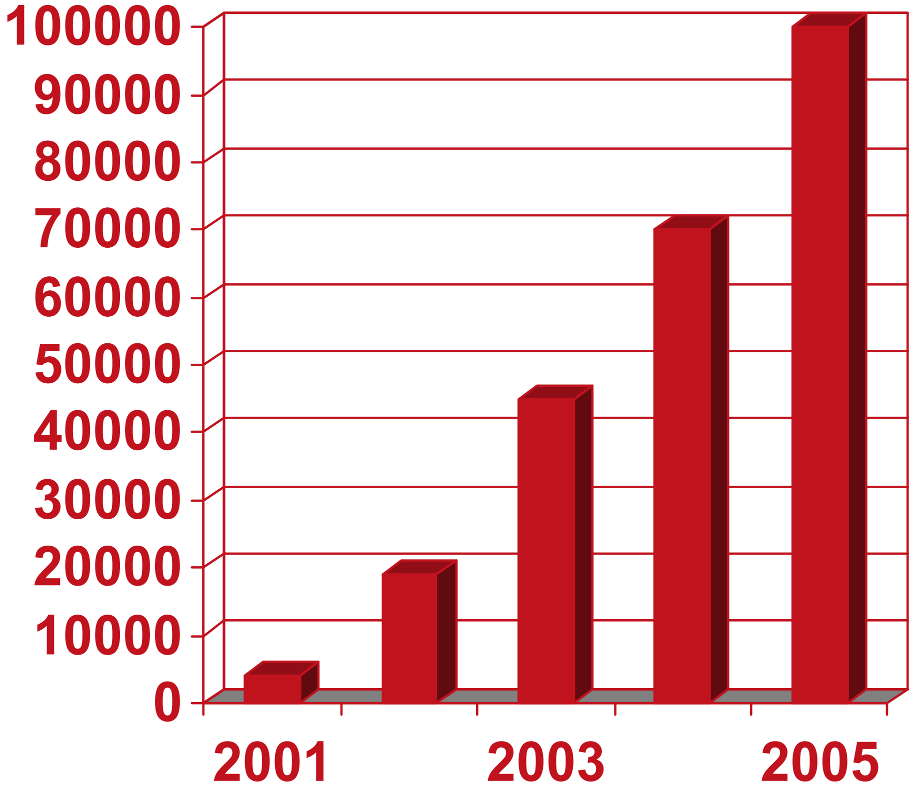
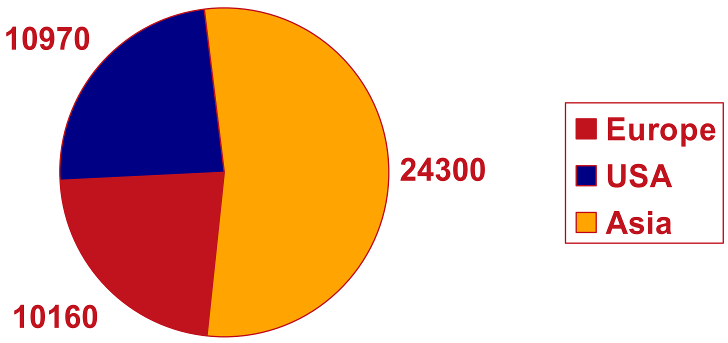
- **In wireless networks there is a need to conserve battery life.**
- **It is preferable for a MS to transmit and receive in contiguous timeslots and then go into sleep mode**
  - Rapidly switching between transmit, receive and sleep modes can increases battery consumption
- **However this preference needs to be balanced against the need to maintain QoS levels.**
  - Efficient sequencing for power can introduce jitter, which degrades QoS

Mobility in IP Wireless Networks

Growth of Wi-Fi Hotspots



2003: Hotspots by region



Source: Pyramid Research, 18th November 2003

Mobility

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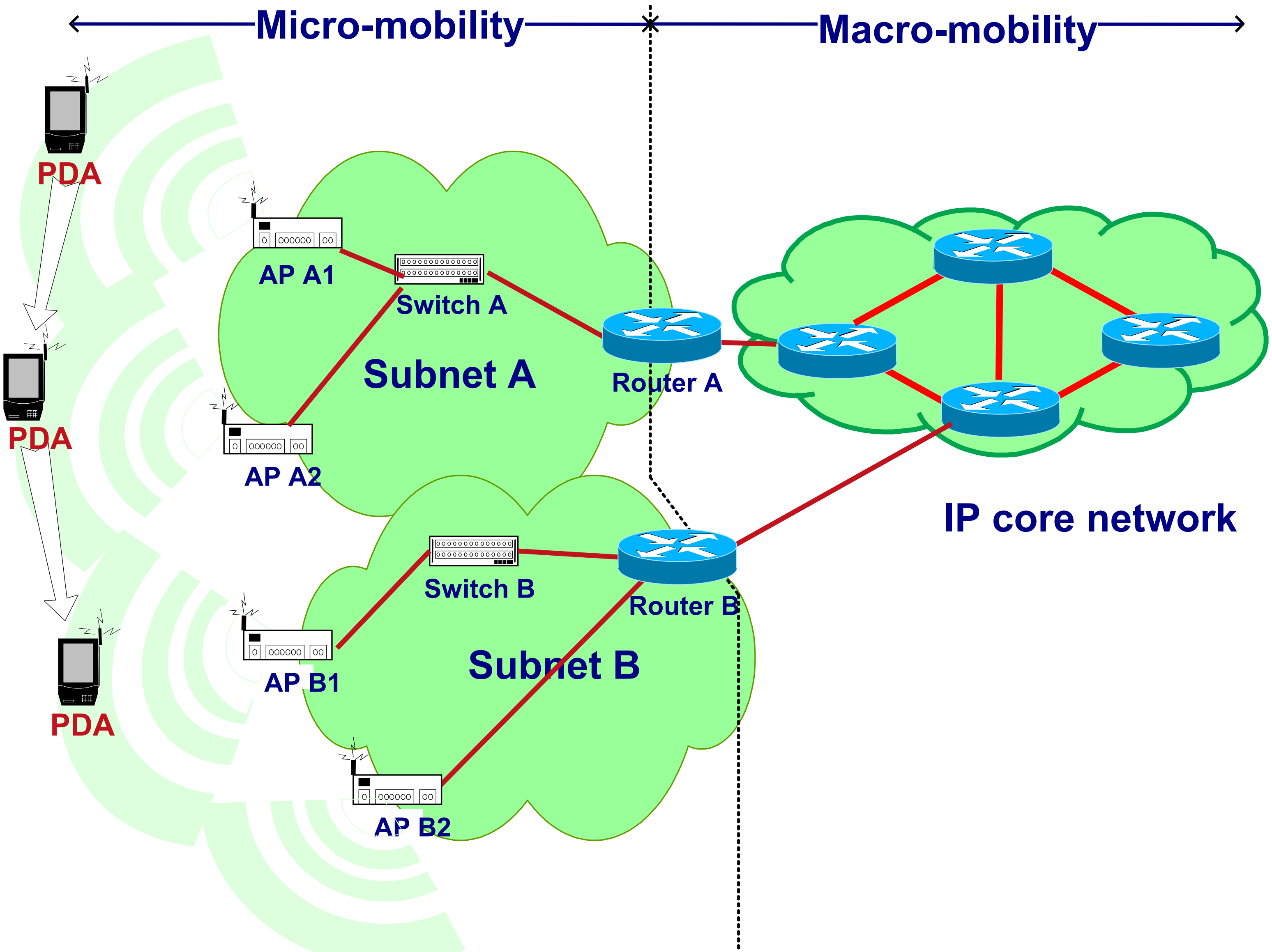
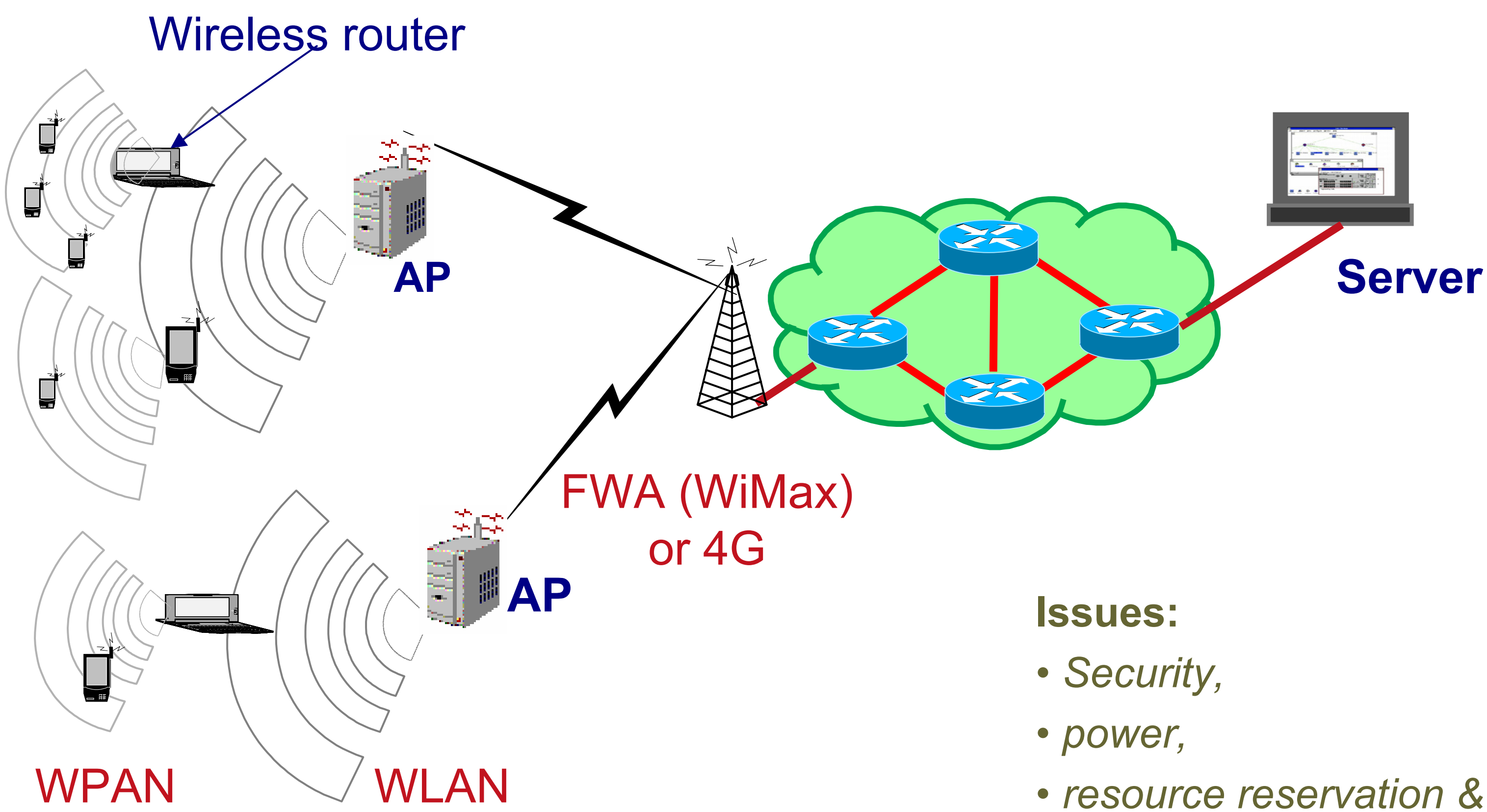
- The increase in WLAN hotspots will drive the demand for some level of mobility
  - Hotzones (e.g. London's Piccadilly)
- Two levels of mobiltiy in IP based networks
- Macro-mobility is addressed by Mobile IP
  - Introduces a large signalling load into the core network
- Micro-mobility is currently under consideration by a number of proposals: cellular IP, Hawaii, etc
  - These protocols seek to isolate the signalling from the core network
- Eventually Roaming between WLANs and cellular systems will be supported
  - This is currently underway

Micro & Macro mobility



Future trends in mobility

Routing Strategies for Multi-Hop Wireless Networks



Issues:

- *Security,*
- *power,*
- *resource reservation & QoS*

Challenges of routing in MANETs

- Topology Dynamics
- Resource limitations: bandwidth, energy capacity, computing power, screen size, etc.
- Variable link capacity
- There can be no Hard QoS guarantees
  - The MANET environment is too dynamic
  - Need to select QoS routes based on the resource metrics
- Two problems in MANETS:
  - Next Hop Racing
  - Rebroadcast Redundancy

Problems in MANET routing

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"Next-hop racing" problem [Li et al]

- During route discovery the next hop of a constructing route is randomly selected (reactive);
  - No guarantee on the quality of a route;
- No guarantee the shortest path will be chosen
  - The first path found at the destination is the "shortest path" among all the possible paths randomly created during this route discovery session, rather than among <u>all</u> the possible paths from the source to the destination;
- The destination has to wait for all the RREQ's to select an appropriate route.
  - This results in extra delay

"Rebroadcast redundancy" problem

- ***All nodes except for the destination rebroadcast the RREQ (Route REQuest);***
  - ***RREQ broadcast results in collisions;***
  - ***RREQ broadcast consumes much power;***
  - ***Each bit Consumes certain power being Tx'd and Rx'd;***
- **Power characteristics of a typical WLAN card (ORINOCO PC Card -Gold 012352/G)**

Doze Mode	10 mA
Receive Mode	180 mA
Transmit Mode	280 mA
Power Supply	5 V

- **Receiving consumes most power in the network!**

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4th Generation Wireless Networks

What is 4G?

- Its not just high data rates
- Evolved from 3G architecture
- Based on cellular, but will incorporate WLAN technologies (e.g. in Hotspots)
- IP and non-IP traffic
- Ubiquity:
  - *Ad-hoc,*
  - *Sensor nets*
  - *White goods*
- Open systems:
  - *Programmable software radio (e.g. Cellphones, PDAs)*
  - *Programmable network components (e.g. Thin Access Points)*

4G systems objectives

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- High-speed transmission (50-100 Mbps cell throughput)
- Larger capacity (~10 times greater than 3G)
- Use of microwave band (3~6 GHz)
- Low system costs (<< 3G costs!)
- Next Generation Internet (IPv6, QoS)
- Seamless services
- Flexible network architecture

Source: NTT DoCoMo

4G system architecture

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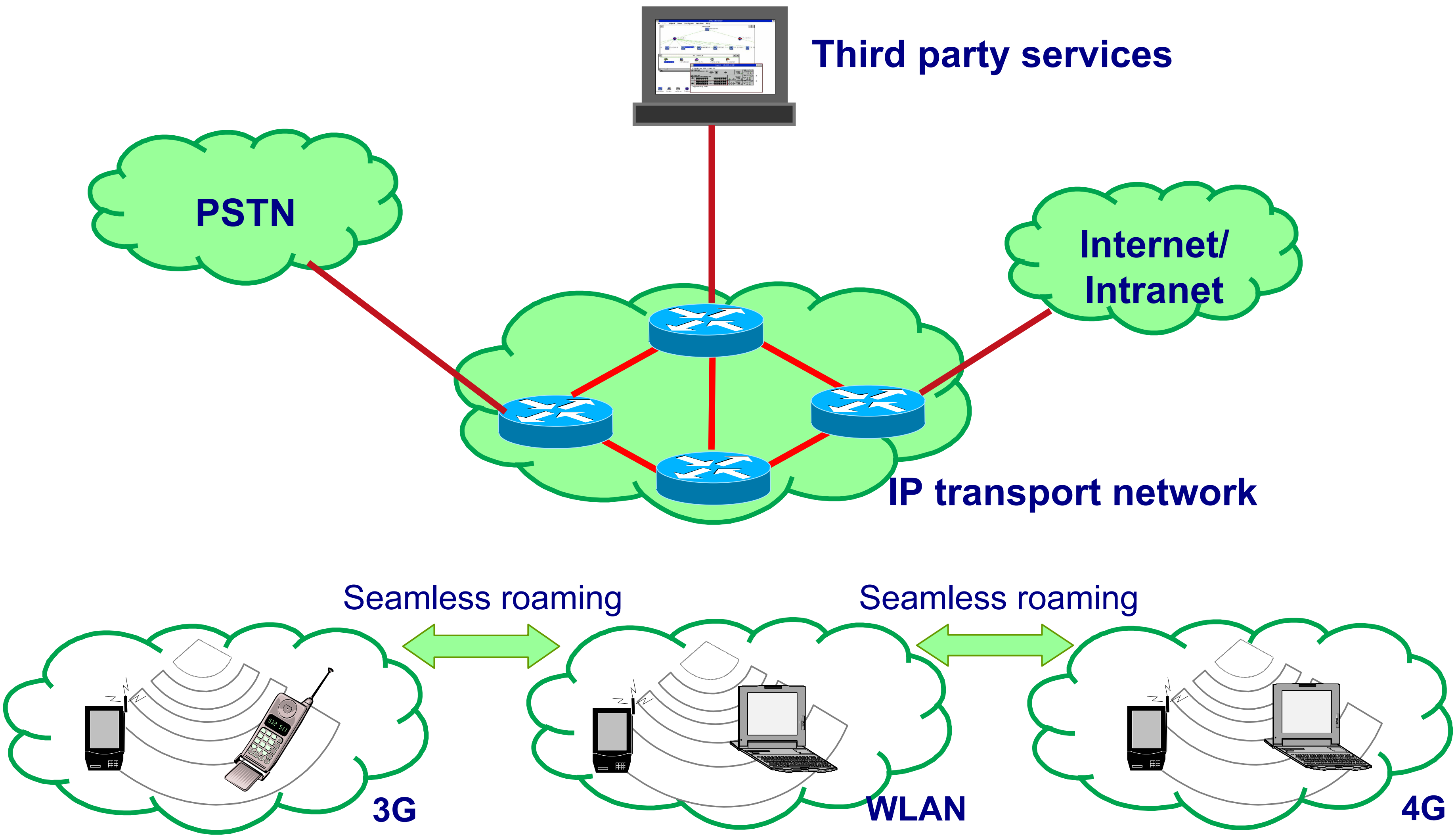
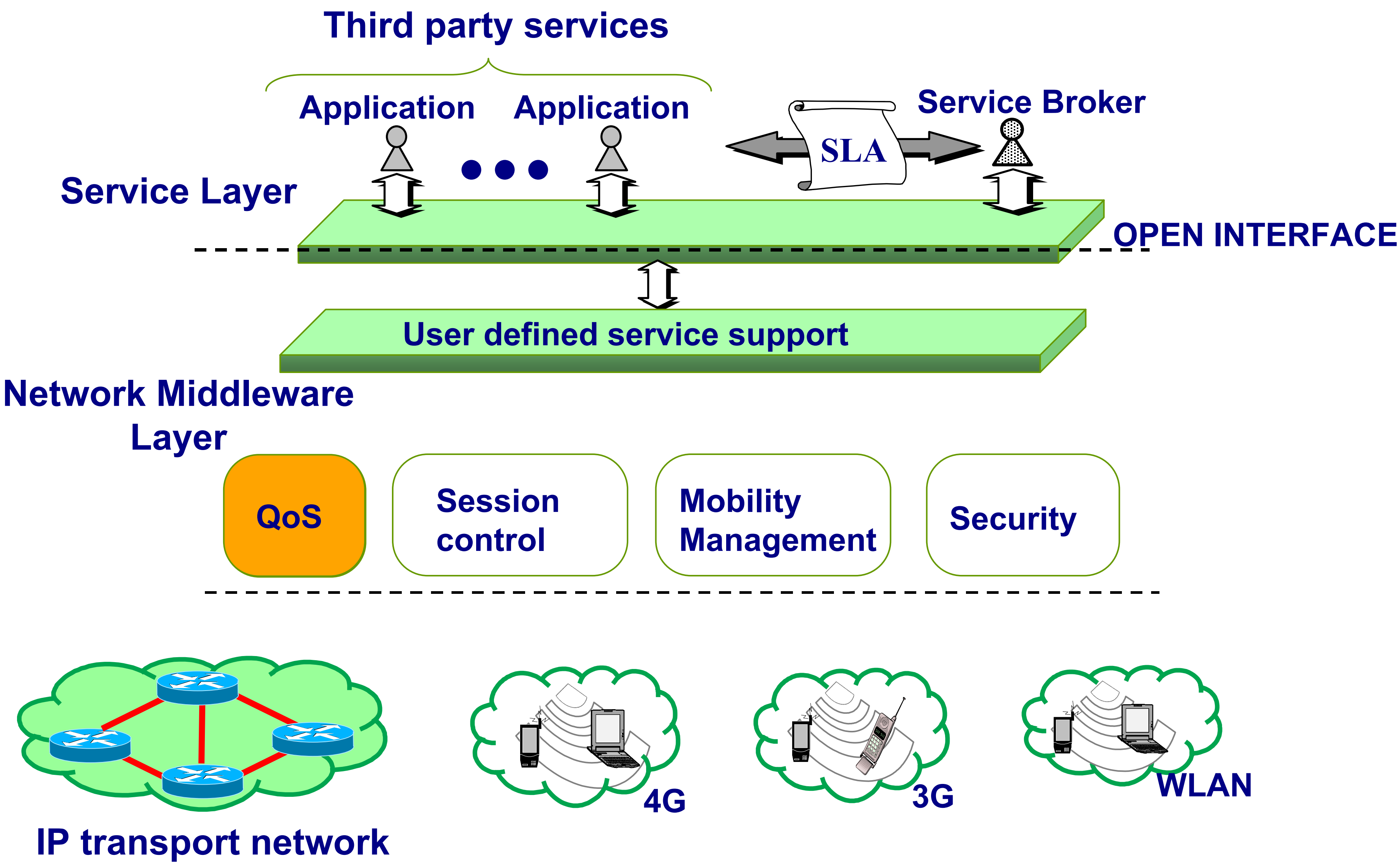


Network Middleware Services Support



Some Future Trends

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Programmability

- Each mobile node can declare its capabilities upon registration with the AP
- The PEPs (WALs) in the mobile nodes can be customised
  - *can download specific functions/modules*
  - *e.g. enhanced FEC, header compression etc.*
- Potential for "Zeroconfigurability"

New Traffic

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How can we handle New types of traffic ?

- Voice and Video traffic characteristics are well known
- Similar for many data applications
  - Http, Email, FTP etc
- Embedded Communications
  - Pervasive computing
  - SOC
- Multi-sensory information

Supporting
Multi-sensory information

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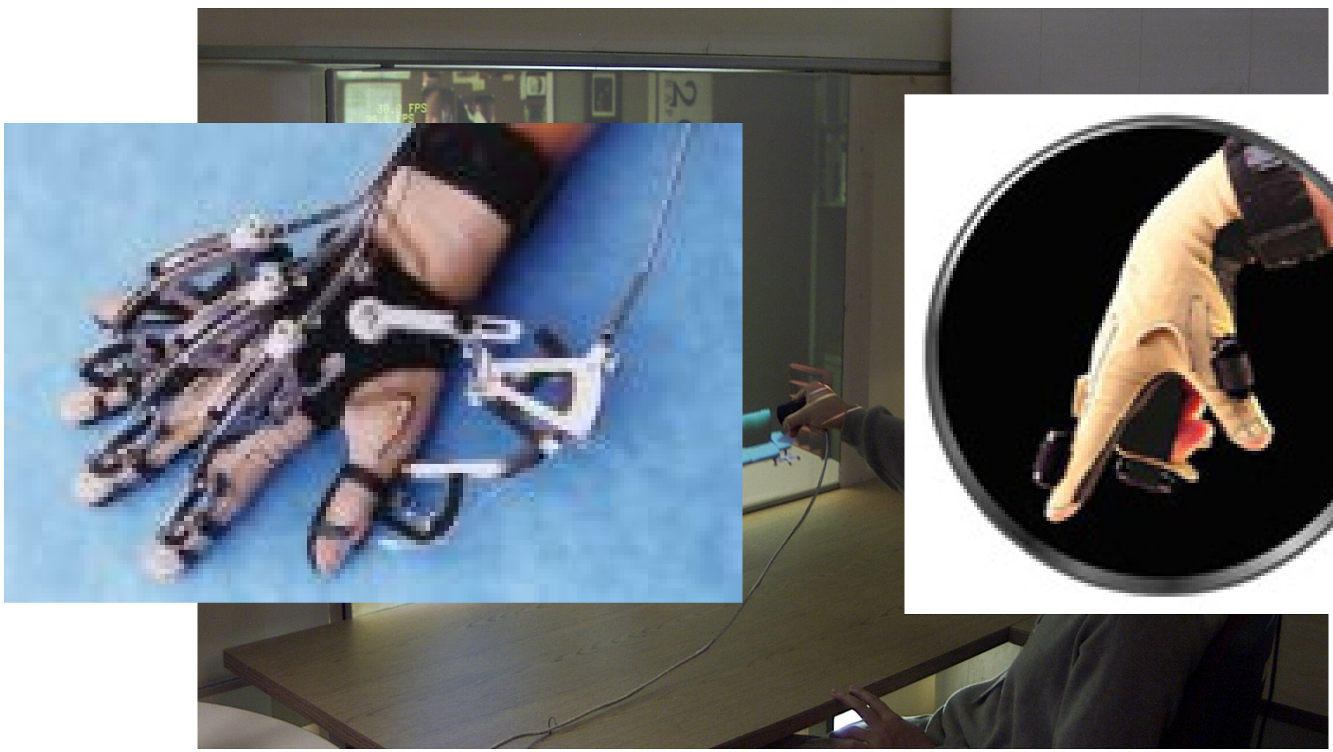
- Not just voice, & Video
- Augmented Reality (VR+)
- Haptic information ("touch and feel")



- Networked Force requires different QoS!

Management

- Need a scaleable management architecture
  - From large core networks to small PANs and sensor networks
- Management functions will be distributed into the network nodes
  - They can also be integrated with low-level devices for PANs etc.
- How do you manage a SOC?

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Thank you !