5G Overview

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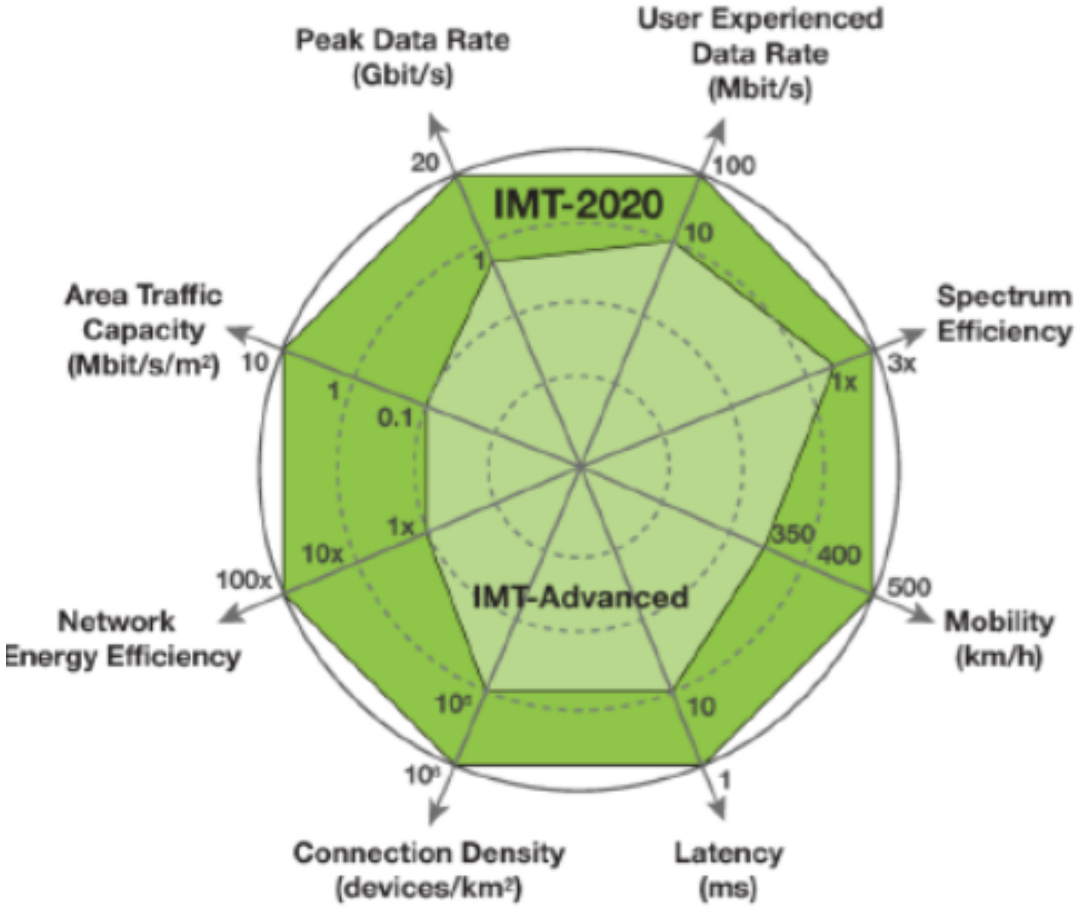
5G Views

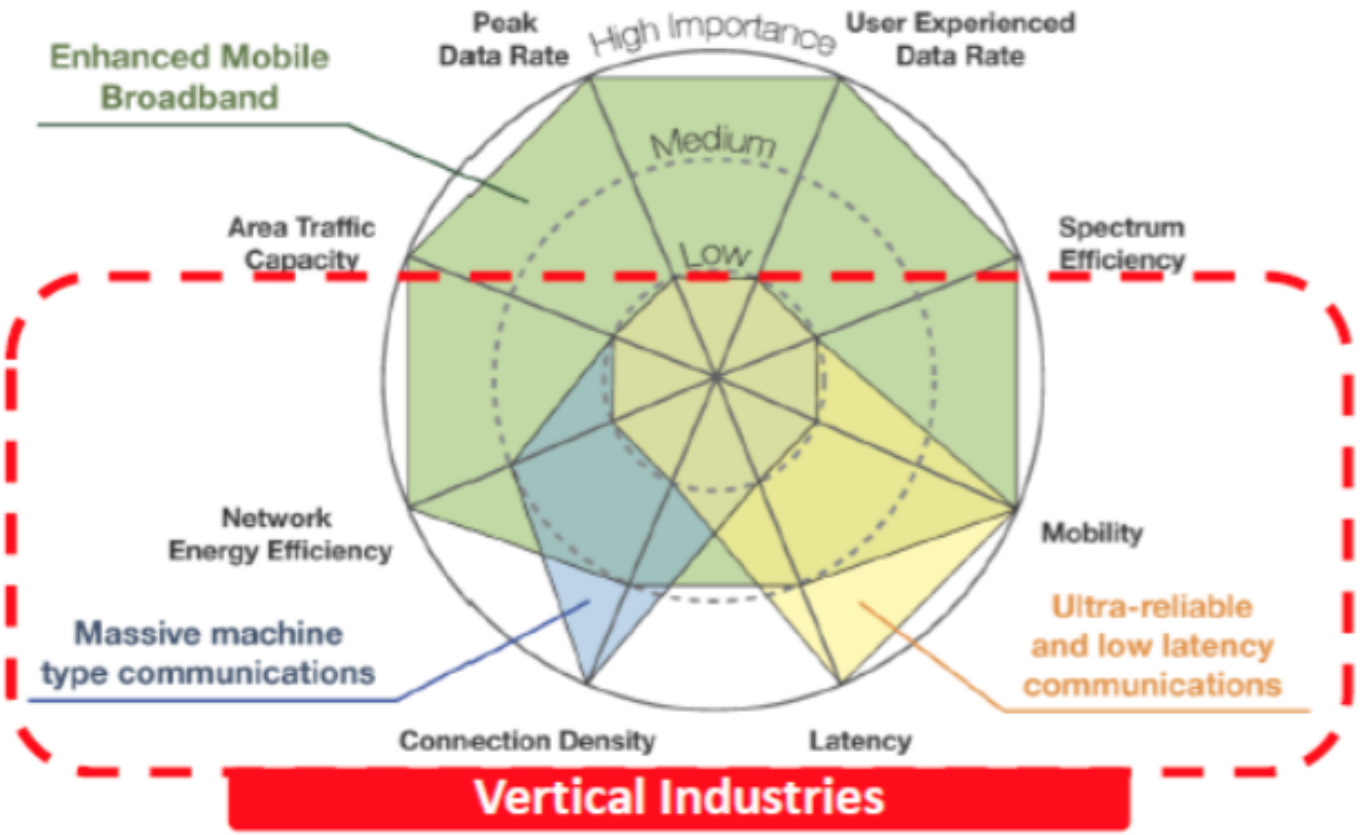
- *View 1 – The hyper-connected generation:* A blend of technologies (pre-existing) covering 2G, 3G, 4G, Wi-fi, Wimax, etc.
  - higher coverage and availability
  - higher network density in terms of cells and devices
  - greater connectivity for M2M services and IoT
  - New D2D connections
  - New radio technology to enable low power, low throughput field devices
- *View 2 – Next-generation radio access technology:* traditional new generation defining view, with specific indicators targets, e.g., data rates, latency, coverage
  - new radio interfaces can be assessed against such criteria
  - Demarcation between technologies that meet the criteria and the ones that do not
- *View 3 – Mix of view 1 and 2?*
- Ref: GSMA

ITU's requirements on 5G (IMT-2020)

Enhancement of key capabilities from IMT-Advanced to IMT-2020

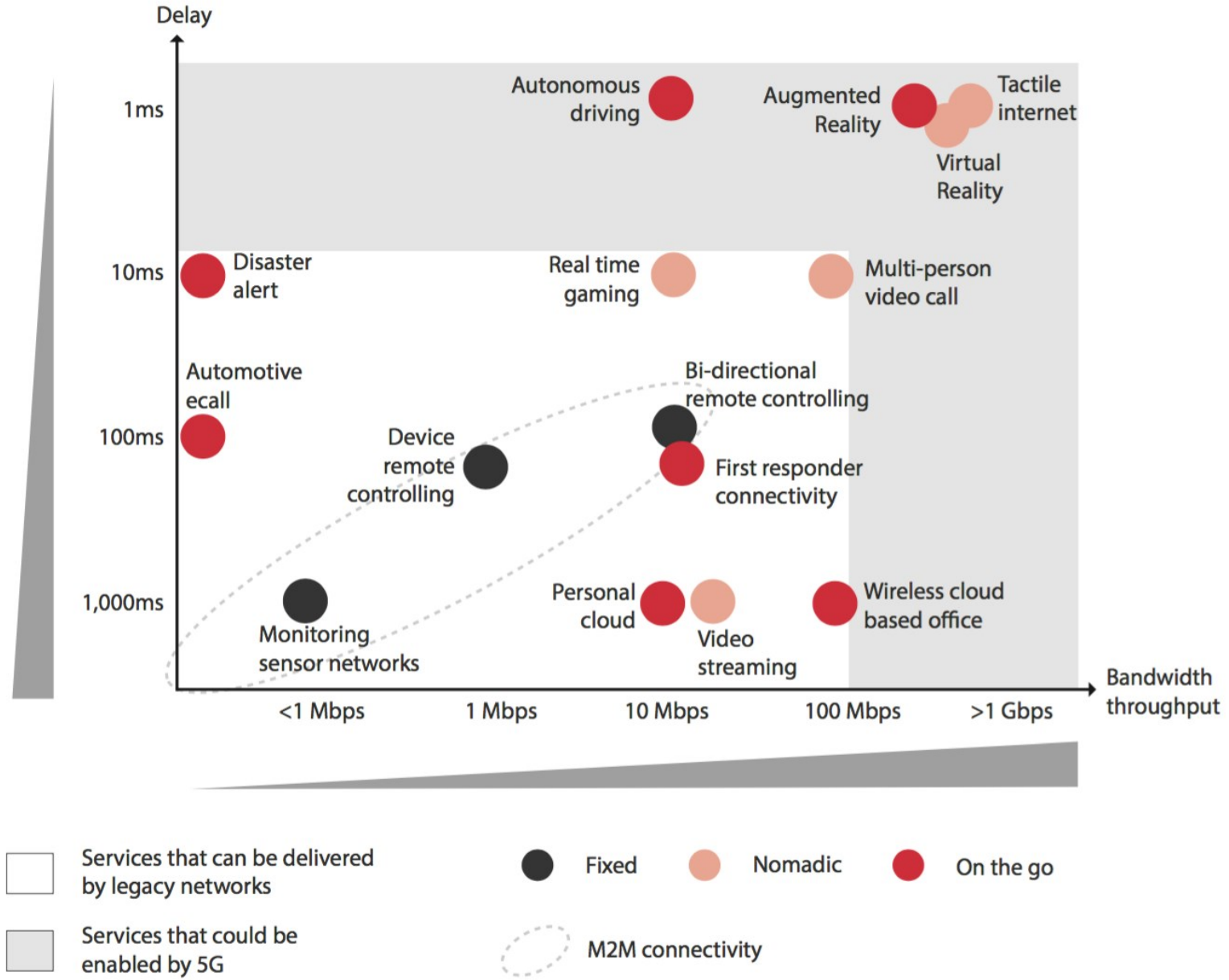


The importance of key capabilities in different usage scenarios



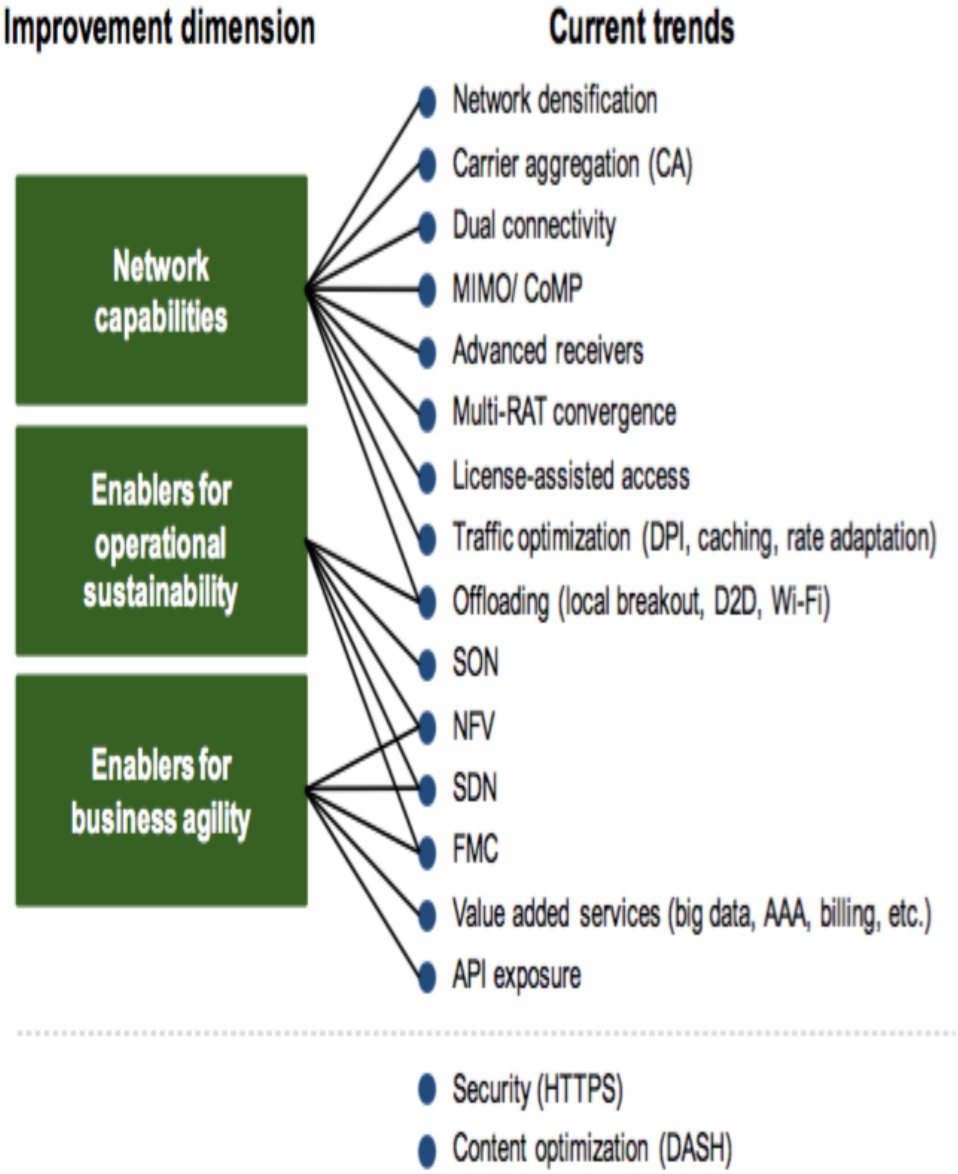
Source: Document 5D/TEMP/625-E, ITU 22nd Meeting of Working Party 5D, San Diego, USA, 10-18 June 2015

Who needs the new targets?



Key Enabling Technologies

- Densification
  - Access Points (Network Topology, HetNets)
  - Large-Scale/Massive MIMO (multiple Inputs multiple outputs antennas)
- Spectral vs. Energy Efficiency Trade-Off
  - Shorter Transmission Distance (Relaying, small cells, D2D)
  - Power Dissipation (MIMO, Antenna Muting)
  - RF Energy Harvesting, Wireless Power Transfer, Full-Duplex
- Spectrum Scarcity
  - Cognitive Radio, Opportunistic Communications
  - mmWave (30-300 Ghz) Cellular Communications
- Software-Defined Network & Virtualization
  - SDN, NFV, SON, Network Resource Virtualization (NRV)
- Novel management & automation



5G Indicators

Performance Indicators	
User experienced data rate (bps)	Minimum achievable data rate for a user in real network environment
Connection density	Total number of connected devices per unit area
Traffic volume density (bps/km2)	Total data rate of all users per unit area
Mobility(km/h)	Relative speed between receiver and transmitter under certain performance requirement
Peak data rate (bps)	Maximum achievable data rate per user
Latency	Delay from the time a packet is sent from transmitter until it is received at the receiver (several definitions exit)

Efficiency Indicators	
Spectrum efficiency (bps/hz/km2)	Data throughput per unit of spectrum resource per area unit
Cost efficiency (bit/$)	Number of bits that can be transmitted per unit cost
Energy efficiency (bit/j)	Number of bits that can be transmitted per joule of energy

Growth Indicators	
Number of 5G subscriptions	Total subscriptions to 5G networks (including pre-paid *active* SIM cards, H2H (voice, data), M2M and M2H communications) 1 Subscription → several devices
Number of 5G connected devices	Total number of 5G connected devices incl. H2H, M2M, D2D 1 device → subscriptions
5G population coverage	Total population within range of 5G signal (whether or not they are subscribers) divided by the total population.
5G network coverage	Total land area covered by 5G signal divided by total land area
5G device ownership	Total connected devices (human & machines communications) within range of 5G signal divided by the total population (average #devices/person)
5G device/connectivity density	Total connected devices (human & machines communications) within range of 5G signal divided by the total land (average #devices/Km2)
5G data traffic	Total data traffic over 5G network (H2H, M2M, H2H, M2H, D2D, etc.)

Measuring 5G Growth Indicators

- Identify 5G networks
  - *View 1* –A blend of tech. 2G, 3G, 4G, Wi-Fi, Wimax, etc. : all networks from the blend →5G nets
  - *View 2* –Traditional generation: net satisfying specific indicators targets (rates, latency) → 5G nets
- Traditional ways of measuring the indicators, e.g., for 3G, 4G
  - Including M2M, M2H and D2D
  - Measure the indicator for each 5G network (including M2M). Total measure estimate:
  - (Indicator net1 + Indicator net2 + …+ Indicator net. N)
    - This measure does not exclude multiple subscriptions
    - Overestimates the indicator → provides the maximum possible value
    - Accurate when indicator measures are not overlapping for different networks
  - Max (Indicator net. 1, Indicator net. 1, …, Indicator net. N)
    - Excludes multiple subscriptions and excludes non overlapping measures
    - Underestimate indicator→ Min possible value
    - Accurate when subscriptions/network are overlapping
  - (Indicator net.1 U Indicator net. 1 U …U Indicator net. N)
    - More precise measure that excludes multiple subscriptions but need precision data
  - Measures can include accuracy & different methods of measurements for different indicators

Examples of 5G Growth Indicators

- Example 1 Network coverage could be estimated as
  - (Land Area 1 U Land Area 2U …U Land Area N)/Total Land Area
  - Max (Land Area 1, Land Area 2, …, Land Area N)/Total Land Area (underestimate)
  - (Land Area 1 +Land Area 2+ …+Land Area N)/(Total Land Area) (overestimate)
- Example 2 Number of subscriptions could be estimated as:
  - # subscriptions net 1+ # subscriptions net 2 + …+ # subscriptions net N
  - Max (# subscriptions net 1, # subscriptions net 2, …, # subscriptions net N)
  - Subscriptions net 1 U subscriptions net 2 U …U subscriptions net N
- Example 3: Number of connected devices (>> # of subscriptions) could be measured as
  - Sum of # devices by network (incl. M2M, D2D)
    - Measure may include or exclude overlapping
    - Registered devices or connected devices, e.g., keeping database of device ID in different 5G networks
  - 5G Subscriptions X (number of devices/subscription)
  - Number of sold capable devices for each “5G” technology
- Example 4: Traffic growth
  - Sum of traffic for each network(including M2M)
    - Take into account offloading methods e.g., D2D, WiFi, etc.

Conclusions & Recommendations

- **5G is in the early phase of design**
  - No clear definition yet, different views → measuring the indicators depends on the adopted 5G view
  - Novel services & applications, new QoS requirements, more differentiation, M2M, D2D, H2H, H2M, etc.
  - Prepaid more challenging then postpaid for measuring the indicators → SIM is not locked to a device
  - Latency goal (1ms) and high data rate expected
    - Cost: Who wants to pay?
  - Spectrum efficiency vs Energy efficiency, Interference with critical services
- **Recommendations**
  - Put in place data/information protection policy
  - Recommend precise data collection from service providers & precise data compilation from regulators
  - Put in place open data policy to promote innovation and economy
    - Taking into account security and privacy
  - Promote IoT through IoT policy, technologies and applications
    - Applications, projects and policies could be on regional or subregional levels
  - Leapfrog to data communication technologies (4G, 5G) to accommodate IoT