5G Introduction:

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Introduction: IMT 2020 & 5G
**IMT-2020 & 5G**

**IMT-2020** is a name for the systems, components, and related elements that support enhanced capabilities beyond those offered by IMT-2000 (3G) and IMT-Advanced (4G) systems.

**5G** : 3GPP system that meets the performance requirements for an IMT-2020 technology.
Standardization – ITU & 3GPP

- Processes-Timelines -Roadmap
International Telecommunication Union (ITU)

ITU-R

Radiocommunication:
Manages radio-frequency spectrum and satellite orbits, ensures interference free operations of radiocommunication systems

ITU-T

Standardization:
Produces standards and defines tariff principles for international telecommunication services

ITU-D

Development:
Facilitates the creation, development and improvement of telecommunication and ICT
IMT-2020 radio interface standardization process

- Development plan
- Market/services view
- Technology/research kick off
- Vision - IMT for 2020
- Technical performance requirements
- Evaluation criteria
- Invitation for proposals
- Sharing study parameters (IMT-2020)
- Technical proposals
- Evaluation Groups
- Methodology
- Consensus building
- Spectrum/band arrangements
- Decision & radio framework
- Detailed IMT-2020 radio specifications
- Future enhancements

Diagram showing the timeline and key steps:

- 2014: Report Technology trends (M.2320)
- 2015: Report IMT feasibility above 6 GHz (M.2376)
- 2016: Recommendation Vision of IMT beyond 2020 (M.2083)
- 2017: Modifications of Res. 56/57 and new Res. 65
- 2018: Technical Performance Requirements
- 2019: Evaluation Criteria & method
- 2020: Requirements, Evaluation Criteria, & Submission Templates
- Workshop
- Evaluation
- Consensus building
- Outcome & Decision
- IMT-2020 Specifications
Overview of timeline for IMT development and deployment

1985
SQ Adopted FPLMTS

2000
IMT-2000 Rec. ITU-R M.1457 (1st release)

2003
Vision Rec. ITU-R M.1645

2012
IMT-Advanced Rec. ITU-R M.2012 (1st release)

2015
IMT-2020 Vision

2020
IMT-2020

(*) Deployment timing may vary across countries.
Key ITU IMT-2020 Documents

• ITU-T Y.3101 : Requirements of the IMT-2020 network

• ITU-R M.2083 : Framework and overall objectives of the future development of IMT for 2020 and beyond

• ITU-R M.2410 : Minimum requirements related to technical performance for IMT-2020 radio interface(s)

• ITU-R M.2411 : Requirements, evaluation criteria and submission templates for the development of IMT-2020

• ITU-R M.2412 : Guidelines for evaluation of radio interface technologies for IMT-2020
3rd Generation Partnership Project (3GPP)

- 3GPP unites Seven telecommunications *standard development organizations* (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as “Organizational Partners”.

- The project covers cellular telecommunications technologies, including radio access, core network and service capabilities, which provide a complete system description for mobile telecommunications.

- The three **Technical Specification Groups** (TSG) in 3GPP are:
  - Radio Access Networks (**RAN**),
  - Services & Systems Aspects (**SA**),
  - Core Network & Terminals (**CT**)
Release timelines:
https://www.3gpp.org/specifications/releases

March 23, 2020

A shift of the Rel-16 timeline was approved at TSG#87 plenary e-meetings.
• Rel-16 Stage 3 freeze now June 2020 (shifted by 3 months)
• Rel-16 ASN.1 and OpenAPI specification freeze in June 2020 (stays as planned)

At the same meeting, a TSG and WG leadership proposal to shift the Rel-17 timeline by 3 months was also agreed:
• Rel-17 Stage 3 freeze September 2021
• Rel-17 ASN.1 and OpenAPI specification freeze: December 2021
5G Usage scenarios
5G Usage Scenarios

- Enhanced Mobile Broadband (eMBB)
- Ultra-reliable and low latency communications (URLLC)
- Massive machine type communications (mMTC)
1. Enhanced Mobile Broadband (eMBB):
eMBB seeks to significantly improve the data rate, latency, user density, capacity, and coverage of mobile broadband access to allow the live streaming of AR/VR applications, even in crowded environments and data driven use cases.
2. Ultra-reliable and low latency communications (URLLC): Stringent requirements for latency and availability capabilities. e.g. autonomous vehicles, transportation safety, smart grids, remote medical surgery, industrial automation.
3. Massive machine type communications:

This use case is characterized by a very large number of connected devices typically transmitting a relatively low volume of non-delay-sensitive data. Devices are required to be low cost, and have a very long battery life. E.g. embedded highway sensors, parking sensors, smart utility meters, asset tracking, smart agriculture, smart cities, smart home, etc.
5G usage scenarios

Enhanced Mobile Broadband

- Gigabytes in a second
- 3D video, UHD screens
- Work and play in the cloud
- Augmented reality
- Industry automation
- Self Driving Car
- Mission critical application e.g. e-health

Future IMT

- Smart Home/Building
- Voice
- Smart City
- Massive Machine Type Communications
- Ultra-reliable and Low Latency Communications
5G: Key Capabilities
Eight parameters/key capabilities of IMT-2020:


1. **Peak data rate**: Maximum achievable data rate under ideal conditions per user/device (in Gbit/s).

2. **User experienced data rate**: Achievable data rate that is available ubiquitously across the coverage area to a mobile user/device (in Mbit/s or Gbit/s).

3. **Latency**: The contribution by the radio network to the time from when the source sends a packet to when the destination receives it (in ms).

4. **Mobility**: Maximum speed at which a defined QoS and seamless transfer between radio nodes which may belong to different layers and/or radio access technologies (multi-layer/-RAT) can be achieved (in km/h).
5. **Connection density**: Total number of connected and/or accessible devices per unit area (per km²).

6. **Energy efficiency**: Energy efficiency has two aspects:
   - on the network side, energy efficiency refers to the quantity of information bits transmitted to/received from users, per unit of energy consumption of the radio access network (RAN) (in bit/Joule);
   - on the device side, energy efficiency refers to quantity of information bits per unit of energy consumption of the communication module (in bit/Joule).

7. **Spectrum efficiency**: Average data throughput per unit of spectrum resource and per cell (bit/s/Hz).

8. **Area traffic capacity**: Total traffic throughput served per geographic area (in Mbit/s/m²).
Other capabilities

May be required for to make future IMT more flexible, reliable, and secure when providing diverse services in the intended usage scenarios:

• Spectrum and bandwidth flexibility
• Reliability
• Resilience
• Security and privacy
• Operational lifetime
Key capabilities of 5G/IMT-2020 compared with those of 4G/IMT-Advanced
Importance of key capabilities for different usage scenarios

- eMBB (Enhanced Mobile Broadband)
- mMTC (Massive Machine Type Communications)
- URLLC (Ultra-Reliable and Low Latency Communications)
**IMT-2020 RAN latency requirement**

- **User-plane latency**
  - defined as the one-way time to deliver an packet from the layer 2/3 SDU ingress point to the layer 2/3 SDU egress point of the radio interface
  - assuming unloaded conditions (i.e., a single user) for small IP packets (e.g., 0 byte payload + IP header), for both downlink and uplink

- **Control-plane latency**
  - the transition time from a most “battery efficient” state (e.g. Idle state) to the start of continuous data transfer (e.g. Active state)

<table>
<thead>
<tr>
<th></th>
<th>eMBB</th>
<th>URLLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>User-plane latency requirement</td>
<td>4ms</td>
<td>1ms</td>
</tr>
<tr>
<td>Control-plane latency requirement</td>
<td>Minimum: 20ms, encouraged: 10ms</td>
<td></td>
</tr>
</tbody>
</table>

3GPP 5G/NR RAN latency requirement*

- **User-plane latency**
  - The time it takes to successfully deliver an application layer packet from the layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point via the radio interface in both uplink and downlink

- **Control-plane latency**
  - the time to move from a battery efficient state (e.g., IDLE) to start of continuous data transfer (e.g., ACTIVE)

<table>
<thead>
<tr>
<th></th>
<th>eMBB</th>
<th>URLLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>User-plane latency requirement</td>
<td>4ms</td>
<td>0.5ms**</td>
</tr>
<tr>
<td>Control-plane latency requirement</td>
<td>10ms</td>
<td></td>
</tr>
</tbody>
</table>

* Reference: “Study on Scenarios and Requirements for Next Generation Access Technologies”*, 3GPP TR38.913 v14.2.0 (2017-03)

** With ultra-reliable requirement (<10⁻⁶ RLC PDU error), the latency requirement may get relaxed to 1ms
- **Simulation** (including system-level and link-level simulations, according to the principles of the simulation procedure).
- **Analytical** (via calculation or mathematical analysis).
- **Inspection** (by reviewing the functionality and parameterization of the proposal).

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Indoor Hotspot-eMBB</th>
<th>Dense Urban-eMBB</th>
<th>Rural-eMBB</th>
<th>Urban Macro-mMTC</th>
<th>Urban Macro-URLLC</th>
<th>Evaluation methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Peak data rate</td>
<td>Downlink: 20 Gbps, Uplink: 10 Gbps</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Analytical</td>
</tr>
<tr>
<td>2 Peak spectral efficiency</td>
<td>Downlink: 30 bps/Hz, Uplink: 15 bps/Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Analytical</td>
</tr>
<tr>
<td>5 Spectral efficiency</td>
<td>Uplink: 6.75 bps/Hz</td>
<td>Uplink: 5.4 bps/Hz</td>
<td>Uplink: 1.6 bps/Hz</td>
<td></td>
<td></td>
<td>Simulation</td>
</tr>
<tr>
<td>6 Area traffic capacity</td>
<td>10 Mbps/m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Analytical</td>
</tr>
<tr>
<td>13 Bandwidth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Inspection</td>
</tr>
</tbody>
</table>

**Table 2** IMT-2020 radio interface technical performance requirements, required values and evaluation methodology.

Shall support bandwidths up to 1 GHz for operation in higher frequency bands (e.g. above 6 GHz).
5G – Evolution (?)
5G Network Evolution

- **New operation**
  - Manual and simple SON

- **Network Architecture**
  - EPC

- **Air interface**
  - Existing spectrum

- **Spectrum**
  - 6GHz to 100GHz

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- **5G Network Functions**
  - Virtualization + Cloudification

- **New Multiple Access**
  - New Waveform
  - New frame structure
  - Full duplex
  - New coding

- **New spectrum + existing spectrum**

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**4G**

**5G**
Possible deployment Scenario
Standalone (SA)

- Only option for greenfield 5G operators
- Full support for new 5G applications and services: eMBB, mMTC, URLCC
Non-Standalone (NSA)
Non-Standalone (NSA)

Contd..
Migration from EPC to NGC
5G NR
An NG-RAN node is either:
- a gNB, providing NR user plane and control plane protocol terminations towards the UE; or
- an ng-eNB, providing E-UTRA user plane and control plane protocol terminations towards the UE.

*AMF (Access and Mobility Management Function) - NG-C interface*

*UPF (User Plane Function) - NG-U interface*
NR – Key features

- Ultra-lean
- Wide spectrum range
- Forward compatibility
- Multi-antenna
- New capabilities
- New technology components
- Low latency
Massive MIMO, beamforming

2G to 4G

5G
Beamforming

- Dedicated radio signal towards the user
- Enabled by Massive MIMO technology
- Identifies most efficient signal path
- Improves connection reliability
- Reduces interference (unwanted signals)
- Efficient use of spectrum and power
- Allows more simultaneous data streams
Current developments – India
A **5G High Level Forum** was set up by the Government in September 2017 to articulate the Vision for 5G in India and to recommend policy initiatives and action plans to realize this vision. The 5G High Level Forum is chaired by the Secretary, DoT.

The High Level Forum appointed a Steering committee chaired by Prof. A J Paulraj of Stanford University, USA, to advance these initiatives. The Committee, with Prof. A J Paulraj as Chair, was charged to submit its report by August 22, 2018 on matters related to 5G deployment.

- **Making India 5G Ready**, released in August 2018 by the 5G High Level Forum, under the overview of the Department of Telecommunications. The forum included members from other areas of government (the Ministry of Electronics and Information Technology, and the Department of Science & Technology), industry (including mobile operators Reliance Jio, Bharti Airtel and BSNL) and academia.
A White Paper on **Enabling 5G in India**, released in February 2019 by the Telecom Regulatory Authority of India (TRAI); this included detailed insights into enabling 5G deployment in India.
The Government has launched a program titled ‘Building an End-to-End 5G Test Bed’ to advance innovation and research in 5G. This three year program began in March 2018, with a budget authorization of Rs 2,240 million. The program has been awarded to IIT Madras, IIT Hyderabad, IIT Delhi, IIT Kanpur, CEWIT, SAMEER and Indian Institute of Science (IISc), Bangalore. The program envisages close collaboration between the universities and small technology companies.

The goal of the program is to build proof-of-concept 5G prototypes that are broadly compliant with the 3GPP standards. Several smaller academic R&D programs around 5G themes have also been funded by DST and MEITY.

Ericsson has installed the first public access 5G test bed at IIT Delhi in July 2018 for developing applications in the broadband and low latency areas providing access to the industry and institutions to work on India specific usage scenarios and applications. The industry is encouraged to take lead and establish more public test beds in the country.
A number of operators and vendors have already entered into agreements and set plans for trials:

• Bharti Airtel and Huawei have successfully conducted India’s first 5G network trial under a test setup at Airtel’s network experience centre in Manesar, Gurgaon, achieving a user throughput of more than 3 Gbps. Bharti Airtel has signed a memorandum of understanding (MoU) with Nokia and Ericsson to support the company in its preparations for 5G rollout.

• Vodafone Idea has also proposed 5G trials with multiple vendors including Huawei and Ericsson.

• Samsung will conduct 5G field trials in New Delhi in 2019, and is working closely with the DoT. Samsung is also likely to be one of Jio's partners for 5G field trials.

• BSNL has signed an MoU with Ciena to conduct field trials with the goal of a commercial launch by 2020. Ciena and BSNL intend to jointly evaluate fronthaul, midhaul and backhaul transport-based use cases and scenarios to address resiliency requirements and latency concerns.

https://www.business-standard.com/about/what-is-5g
SIXTY-ONE COMMERCIAL 5G NETWORKS IN 34 COUNTRIES

Nearly 10% of all LTE operators have now deployed 5G; nearly 8% have launched 5G

- By the end of 2019 348 operators in 119 countries had announced they were investing in 5G.
- 77 operators had announced that they had deployed 3GPP compliant 5G technology in their networks.
- A total of 61 operators in 34 countries had launched one or more 3GPP-compliant 5G services:
  - Of those...
  - 49 operators had launched 3GPP-compliant 5G mobile services (46 full launches, 3 limited availability launches).
  - 34 operators had launched 3GPP-compliant 5G FWA or home broadband services (27 full launches, 7 limited availability launches).
In January 2020, the number of announced 5G devices exceeded 200.

By mid-April over 280 devices had been announced, of which at least 95 are commercially available.
Announced 5G devices, by form factor

- Phones: 38.2%
- CPE: 27.9%
- Modules: 16.6%
- Hotspots: 6.7%
- Laptops (notebooks): 1.8%
- Industrial grade CPE/routers/gateways: 1.8%
- Others: 7.1%
Operators have announced over 600 demos, tests or trials

Early tests and trials focused on: new radio (NR) interfaces operating in spectrum bands not previously used for mobile telecoms services; network slicing to support delivery of services tailored to specific types of customer or service; combinations of technologies such as massive MIMO, or complex beam-forming that are needed to achieve very high speeds; and backhaul, cloud- and edge-computing arrangements to support very low latencies. Recent tests have been looking at issues such as: interoperability of SA 5G NR with core network systems; delivery of 4K ultra-HD CCTV and broadcast services; and use of 5G for robotic surgery. Trials have also focused on testing the spectrum bands likely to be used in any given country, with a lot of activity in C-band spectrum and spectrum at 28 GHz.
Thank you