First ACM/IEEE
Next G Summit

6TH GENERATION: AT WHAT COST?

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• General Manager, Telecom Standards at Reliance Jio Infocomm Limited.
• Two decades of Telecom R&D experience.
• He pursued M.Tech from I.I.T. Roorkee.
• Delegate at ITU-R, 3GPP, TSDSI, and ORAN respectively.
• Actively involved in the modeling, simulation & implementation of various generations of cellular standards working with multiple MNCs during his career.
JOURNEY FROM 5G to 6G: IMT

1. R16 starts 5.5G standardization
2. 6G vision finished before WRC-23, vision workshop in June 2022
3. At the end of 2024, 6G workshop
4. At the end of 2025 or early 2026, 3GPP starts study of 6G (Requirement, SI, WI ...)
5. First specification of 6G finished in 3GPP in 2030

WRC-19 Allocate 5G Spectrum
WRC-23 Discuss 6G Spectrum
WRC-27 Allocate 6G Spectrum
TSDSI Study Group Networks SI70: ITU IMT2030


• TSDSI Study captures the preliminary understanding on 6G Use cases, enabling technologies, KPIs, Network architecture, spectrum aspects.

• TSDSI made contributions towards the IMT.FUTURE TECHNOLOGY TRENDS & IMT.VISION 2030 document based on outcome of this study. [1][2]

• The TSDSI study does not limit its scope to terrestrial communication. It includes Deep space, Satellite & Under water communications use cases.
MEASURES OF TECHNOLOGY COST: CAPEX, OPEX, ENVIRONMENT, SPECTRUM

Global Mobile Data Traffic Forecast by ITU

Telecoms groups jostle for new spectrum

Proceeds ($bn) | Cost of frequency per person ($) (Forecast)
---|---
2006 | 0
08 | 0
15 | 0
16-17 | 0
18-19* | 0
19 | 0
19-20 | 0
20 | 0
20-21 | 0
21-22 | 0

AWS-1 (auction 66) | 90 MHz
AWS-3 (auction 97) | 90 MHz
Incentive auction | 50 MHz
28 GHz auction | 50 MHz
24 GHz auction | 50 MHz
37 and 39 auction | 50 MHz
47 auction | 50 MHz
CBRS auction | 50 MHz
C-band | 50 MHz
3.45-3.55 GHz

* 25% of US
Source: UBS
Operators cost

Energy-saving methods differ between site level, RAN equipment and network planning

Source: GSMA - Mobile Net Zero State of the Industry on Climate Action 2021
Operators cost: Distribution

80% MNO Energy > Network usage
50% of Total > Mobile Network
75% of Mobile Network: RAN sites
Environmental Cost

Greenhouse Gas Protocol

**Scope 1 emissions:**
Direct emissions from owned and controlled sources, including fuel combustion, company vehicles, and fugitive emissions.

**Scope 2 emissions:**
Indirect emissions from generation of purchased electricity, steam, heating and cooling consumed by the reporting company.

**Scope 3 emissions:**
All other indirect emissions that occur in a company’s value chain, including purchased goods and services, business travel, employee commuting, waste disposal, use of sold products, transportation and distribution (upstream and downstream), investments, leased assets and franchises.

## Target Setting

<table>
<thead>
<tr>
<th><strong>SCIENCE BASED TARGETS (SBTs)</strong></th>
<th>• As defined by the Science-Based Targets Initiative to set carbon reduction targets in line with limiting global heating to below 2°C.</th>
</tr>
</thead>
</table>
| **CARBON NEUTRAL** | • Refers to reducing and offsetting carbon emissions from own operations (Scope 1 and 2 emissions).  
  • For MNOs the largest source of Scope 1 and 2 emissions are electricity use for networks and diesel fuel use for transport and generators. |
| **NET ZERO** | • Refers to the criteria used by the UN Race To Zero campaign, which includes reductions in Scope 3 emissions across the whole value chain.  
  • See unfccc.int/climate-action/race-to-zero-campaign |
NEW SPECTRUM & REGULATIONS

Attaining data rates of the order of 100 Gbps require usage of wider bandwidth available in higher frequency bands.

Such initiatives would call for new regulatory models to be implemented.

Some geographies have opened spectrum above 100 GHz encouraging early experimentation in sub-THz bands.
SPECTRUM COST: IMPACT & RESEARCH AVENUES

1. Trade-off between spectrum availability and densification of network deployment.

2. Ex. FS, FSS, IMT technologies to be designed to co-exist in same spectrum.

3. Need for Cooperative game theory to be applied across spectrum access by independent services.

4. Technologies to be capable of co-existent in same Space-Freq-Time by:
   - Waveform design – All standards developed together – mutually dependent.
   - Developing a framework to be followed to allow independent specification development.
   - Cognitive Radio based technologies.
Future Research Avenues: 6G RAN

6G Green Networks:
- Symbiotic radio
- Ambient backscatter communications,
  Reconfigurable intelligent surfaces

AI ML in 6G networks
for
Green communications and computing

Low-power 6G network:
- Adaptive waveforms,
  Battery-less energy harvesting,
  and
- Adaptive modulation and coding techniques

Resource constrained Device Support:
- Cell-free massive MIMO,
  Full duplex and THz communication

Sustainable Green 6G networks
SON techniques
Future Research Avenues: 6G CORE

1. Smart energy management techniques for Balancing Energy demand-supply in 6G networks
2. Energy efficient edge/fog computing, Computation & Data offloading, Cloud-assisted resource management for Green IoT networks
3. Architectures/topologies for Energy-efficient hierarchical IoT-cloud networks
4. Analytical, optimization and experimental approaches for Green communications and computing in 6G networks
5. Redesigning network protocols Reinventing Transport technologies For End to End Low Latency
6. Others ...
## Promising Technologies [1]:

### Light Communications

<table>
<thead>
<tr>
<th>Sr</th>
<th>KPI</th>
<th>RF THz</th>
<th>Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Available bandwidth</td>
<td>Tens to hundreds of GHz</td>
<td>Hundreds of THz</td>
</tr>
<tr>
<td>2</td>
<td>Transmission distance</td>
<td>non-line-of-sight (NLOS)</td>
<td>LOS</td>
</tr>
<tr>
<td>3</td>
<td>Electromagnetic radiation</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>4</td>
<td>Data rate achieved</td>
<td>100Gbps</td>
<td>10Gbps</td>
</tr>
<tr>
<td>5</td>
<td>Spectrum regulatory</td>
<td>Licensed</td>
<td>Unlicensed</td>
</tr>
<tr>
<td>6</td>
<td>Penetration ability</td>
<td>Special opaque materials</td>
<td>Transparent materials</td>
</tr>
<tr>
<td>7</td>
<td>Inter-cell interference</td>
<td>serious</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>Cost</td>
<td>expensive</td>
<td>Cheap</td>
</tr>
<tr>
<td>9</td>
<td>Transmission power</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>10</td>
<td>Diffuse reflection losses</td>
<td>High</td>
<td>Low</td>
</tr>
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References

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