Internet of Things (IoT) needs Healthy 5G mmWave Operation

Dr. Suresh Borkar
Illinois Institute of Technology, Chicago
borkar@iit.edu

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Internet of Things (IoT) needs Healthy 5G mmWave Operation

• Introduction to 5G
• 5G Operation in mmWave Spectrum
• Major Issues and Mitigations
  – Propagation and Coverage
  – Biological Impact
• Concluding Remarks
Cellular Wireless Evolution

Cloud

Server + Infrastructure

Access/Edge

Device

Feature Phone

Voice

1G, 2G
1980’s, 1990’s

Smart Phone

+Data/video

3G, 4G
2000’s, 2010’s

+Sensors

+Machine Traffic

5G
2020’s

5G Issues and mitigations ver 1
Estimated Devices on Internet of Things (IoT) in 2025*

World Population 8 B => 10 devices / person Massive M2M Traffic

*Internet of Things Connected Devices Installed Base Worldwide from 2015 to 2025, Statista, 2019

5G Issues ands mitigations ver 1
5G Operational Frequencies*

*5G and EMF Explained, [www.emfexplained.info](http://www.emfexplained.info), 2018

5G Issues ands mitigations ver 1
5G mmWave Operation Issues

• Propagation and Coverage
  – High Path Loss Due to Higher Carrier Frequency
    • Significantly Reduced Coverage of Less Than 1 Km
  – Deterioration in Propagation Characteristics due to Environmental Issues, e.g., Humidity and Rain
  – Susceptibility to Blockage
    • Weaker Non-line-of-sight Paths
    • Limited In-building Penetration
  – Coverage Gaps
• Uncertain Environmental and Health Impact
Attenuation for mmWave Frequencies*

*Abdin et al., A System and technology perspective on Future 5G mm-Wave Communication Systems, 2017 IEEE 18th Wireless and Microwave Technology Conference (WAMICON)
Propagation Solutions Options

- **Massive Multiple Input Multiple Output (MIMO) Antennas**
  - High Frequencies => Small Wavelengths => Small Patch Antenna Dimensions => Large Sized Arrays Possible
  - Strengthen Signal Using Multiple Streams
  - Create Narrower Steerable Beams with High Concentrated Power

- **Mesh Networks**
  - Device To Device (D2D) Communications by Bypassing Centralized Base Stations
  - Use Relays to Fill Coverage Gaps

- **Ultra Dense Networks with Small Cell Deployment**
  - Use of Adaptive Steerable Arrays to Overcome Blockage
  - Allow Higher Frequency Reuse Rates
MIMO Antennas*

*ibid, slide #5

5G Issues ands mitigations ver 1
5G 3D Steerable Beams*

*ibid, slide #5
5G Network*

Supplement with mesh networking using D2D communications and Relays

*Bojkovic et al, Research Challenges for 5G Cellular Architecture, TELSIKS, 2015
Health Impact of EM Spectrum

- **Frequency**: $10^2$ to $10^{24}$
- **(MHz)**: $10^6$ to $10^{14}$
- **(GHz)**: $10^8$ to $10^{16}$

**Spectrum Breakdown**:
- **Long Radio Waves**: Radio, TV
- **Microwave**: 0.7 GHz
- **Infrared**: 100 GHz
- **Visible Light**: Non-ionizing
- **Uv Rays**: Ionizing
- **X Rays**: Impact on cells/DNA; may cause cancer
- **Gamma Rays**: Impact on cells/DNA; may cause cancer

**Primary Impact on Body**
- Temperature rise

**Cellular Frequencies**
- Non-ionizing

**5G Issues and Mitigations ver 1**
mmWave Operations for 5G

• Major IoT Operation in the 24 – 60 Ghz
  – Considered Part of 30 Ghz to 300 Ghz Mmwave Range
• High Reflection Rates on the Skin
  – Sweat Gland Become Conductive

• Effect Localized to the Upper Two Layers of Skin
• Possible Burning Sensation and Thermal Injury to Eye
• Primary Measure Incident Power Density (IPD)
• Published Literature Inconclusive on Harmful Effects of mmWaves on Humans, Vegetation, and Environment

IEEE defined maximum Allowable Body Temperature Rise of 1° C
Safely used in airport Security Scanners
Defining Safety Rules for 5G mmWave Operation

- Generally Global Regulatory Agencies
  - Apply Current Sub 6 Ghz Rules All the Way to 100Ghz
    - Incident Power Density (IPD) Levels Of 1 mW/Cm² with Safety Factor of 50
- Concerns
  - Unknown Massive mmWave Traffic
  - Effect on Vulnerable Members of our Society like Infants, Pregnant Women, and Senior Citizens
- Need for Investigation
  - In 2017, a Petition to UN and US FCC by a Group of 180 Scientists, Engineers, and Doctors from 36 Countries
  - Concerns by American Academy of Pediatrics
- Appropriate for Regulatory Agencies to Support Definitive Studies on the Safe Power Limit for 5G mmWave Operation

New rules expected to be in the “vicinity” of current power safety limits
5G Deployment Issues

• Premature Market Introduction Resulting in Adverse Impression about the Technology
  – Standards still to be Finalized by 2020
  – Mitigations to Issues still to be Analyzed and Finalized

• Urban and Rural Digital Divide
  – Higher Requirements on Density, Capacity, and Speed in Urban Areas
    • E.g., Roads with different requirements in Urban and Rural Areas
  – Mitigated by 5G Operations in Different Frequency Bands
    • High density in Urban Areas at mmWave Frequency Bands
    • Reasonable Density in Existing Cellular Frequencies in Rural Areas
Concluding Remarks

• 1G – 4G & 5G Wireless Systems support Multimedia Applications in sub 6GHz Frequency Range
• 5G, a New Paradigm in Wireless Access
  – Massive amount of Machine to Machine (M2M) Traffic
    • 80 B devices connected by 2025
  – A new domain of mmWave Operation
• Management of Key Issues for M2M mmWave Operations
  – Propagation Loss and Coverage Gaps
    • MIMO, Steerable Beams, Mesh Networking, Relay and Dense Networks
  – Biological Impact in terms of Skin Temperature Rise
    • Need New Updated Safety Limits for Radiation Power