Advances in Satellite Communications Technology Suitable for IoT

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Satellite Advances Leading to Higher Capacity and Lower Cost

- Very large antenna space-deployable reflectors for geosynchronous satellites (GEO), resulting in
  - Higher G/T and e.i.r.p., higher throughput capacity and efficiency, smaller terminals
- Planned very large low-earth orbit (LEO) and medium earth orbit (MEO) satellite constellations
  - Lower latency, higher network capacity, world-wide coverage, less challenging propagation loss to overcome
- Continued advances in solid-state electronics in both power amplification and digital signal processing
  - Lower cost per watt, smaller physical dimensions
  - Digital beam-forming on space and on ground
  - Fault-torrent circuit design resistant to space radiation
- Increased availability of commercially high capacity Reusable Launch Vehicles
  - Significantly reduction in satellite launch cost to LEO/MEO and GEO orbits

Advances in Communications Techniques

- Power efficient transmission provides near Shannon limit performance
  - Low-density parity check codes (e.g. DVB-S2) and Polar Codes
  - Pre-distortion and pre-coding techniques for low PAPR
- Coherent demodulation at very low signal-to-noise ratio
  - Signal design and receiver processing for rapid acquisition and reliable tracking (e.g. DVB-S2X VLSNR mode)
- Efficient interference cancellation-based Non-Orthogonal Multiple-Access (NOMA) Technique
  - Replaces Aloha or S-Aloha random access
  - Reserving dedicated return channel is no longer required
  - Terminals can transmit whenever they have data to transmit

IoT Applications

- Most of the IoT applications are Fixed or Slow Moving
  - Relatively simple to address
- More challenging applications are wide area, mobile, some require very high reliability

	Indoor	Outdoor/Wide Area
Fixed/Pedestrian	**Consumer Wearable's, Assisted Living/Medical, Smoke detector, Parking, building automation, home automation, alarms, actuators, smart grid, white goods, vending machines, general asset tracking**	**VIP/Pat tracking, Live-stock tracking, Water/Gas metering, parking, lighting, industrial safety/process monitoring, environmental monitoring, waste management**
Mobile		Asset Tracking, smart bicycles, connected cars, automated vehicles

* Source: 3GPP Low Power Wide Area (LPWA) Technologies, GSMA White Paper

Some of the Common Characteristics of Wireless IoT

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- Max. Transmit power: 20-23 dBm
- Cost/devices: $3 -10
- Max Coupling Loss (MCL): 155 dB or higher (164 dB for example)
- Battery life: 10 years desired, less if transmitted more frequently
- Very low data rate to achieve MCL: from <100 bps to 10s of kbps
- Very narrow band, typically using sub 1 GHz unlicensed band (including white space) for long range
- Typically TDD operation instead of FDD
- No strict latency requirements due to low data rate
- Often deployed in less than ideal environment (propagation and environmental) requiring multiple transmissions over time

Unique Advantages of Satellite Connectivity for IoT

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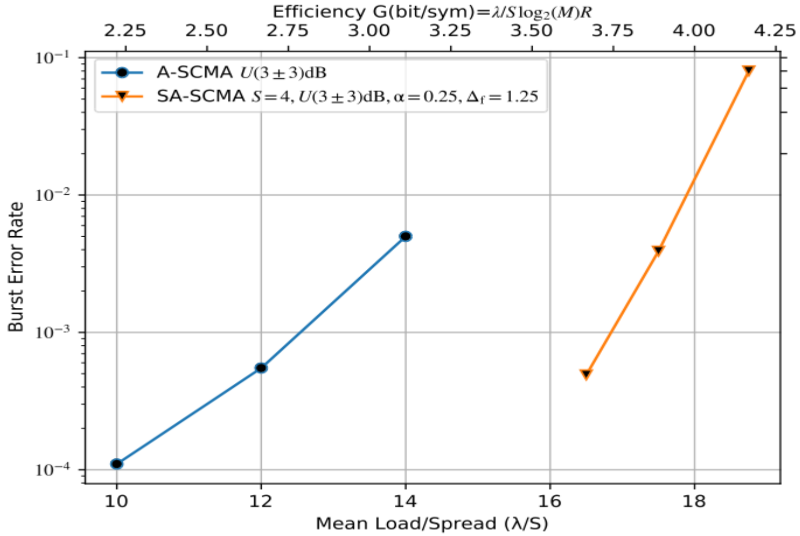
- Wide area coverage including those impossible to access with terrestrial means
  - Ideal for rural or hard to reach terrain
- Global reach: land, ocean, or in the air
- Supports high mobility
- Reliable message delivery with one transmission(< 0.1% PLR)
  - Ideal for mission critical applications
- Broadcast and multicast capabilities
  - Ideal for software updates, supervisory control
- Immune towards natural and man-made disasters
- High capacity using relatively low bandwidth resources
- Key success factor depends on significant user equipment cost reduction and/or on high value applications

Satellite IoT Services

- Current Services
  - INMARSAT has an L-band M2M solutions (fixed satellite, few 100kbps) for messaging and also using satellites to connect LoRA aggregators
  - Globalstar have simplex and duplex solutions
- Iridium will be launching Certus 100 and Certus 20. Thuraya have plans for NGS.
- Terrestar and EML satellites are designed to support handheld terminals with very large reflector antennas
  - Covers North America and Europe Middle Eastern Africa (EMEA) respectively
  - Potentially capable of many applications with small and low cost UE, including
    - Vehicle and asset tracking
    - Flight safety and entertainment
    - Environmental monitoring
    - Homeland security/defense
    - Public protection and disaster response (PPDR)

ACMA/SACMA - a High Capacity NOMA technique

- Asynchronous Code Multiple Access (ACMA) works well with 0dB < E_s/N_o < 6 dB
- Spread ACMA (SACME) provides 4X spreading and 6 dB additional power margin
  - Additional mean traffic handling capacity due to law of large numbers at higher arrival rate



- L-band or S-band applications, with one 31.35kHz channel
  - Typical ACMA terminals can transmit 4.8 kbps continuously sharing with 11 other terminals with the same e.i.r.p.
  - SACMA terminals work well at about 1.2 kbps continuously at about ¼ of the e.i.r.p. while sharing with 65 other terminals
  - Assuming 200 bytes/day, or 1.6 kbit/day, a 31.25 kHz GMR-1 channel within a spot beam can support >3.1 million such devices

Satellite Community Efforts in 5G Wireless Standardization

- 3GPP is currently developing the 5G wireless standards to address three focus areas
  - Enhanced mobile Broadband (emBB)
  - Massive Machine-Type Communications (mMTC)
  - Ultra-Reliable and Ultra-Low-Latency Communications (URLLC)
- Emphases of the Satellite Community are in mMTC and Ultra Reliable Communications
- We have formed a study effort within 3GPP to study how 5G wireless technology may be applied to Non-Terrestrial Networks (NTN) including both satellite and high altitudes platforms (HAPS), Hughes is one of the main contributors in this activity
- Hughes also participates in the study for Non-orthogonal Multiple Access (NOMA) standardization as part of the New Radio (NR) for 5G
- Satellite networks will play a significant role in the 5G era