Spectrum Sharing Initiatives in Unlicensed Bands: Advancements Towards 5G Networks

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Talk Outline

• Evolution of 5\textsuperscript{th} Generation (5G) Networks

• Spectrum Sharing in Unlicensed Bands

• Recent Initiatives in Unlicensed Bands
  ✓ Cellular Technologies
  ✓ IoT Technologies

• Research Challenges and Directions

• Conclusions
Evolution of Telecom Networks

- High speed in tens of Gbps
- Huge number of connected devices (50 billion)
- Significant growth in mobile traffic (366.8 Exabytes per annum)
- Ubiquitous coverage
- Heterogeneous connectivity
- Scalable and new service experience any time and any where
- Ultra-rich Quality of Experience
Global Mobile Data Traffic Growth

- By 2020: Growth of mobile users → two times faster than global population
- By 2020: More people with mobile phones than electricity at home

Source: Cisco VNI Global Mobile Data Traffic Forecast, 2015-2020
Need for More Spectrum in 5G

More Spectrum – From where and how??

Identifying unused spectrum bands
- Spectrum databases

Meeting 5G Spectrum Requirements?

Combining / Aggregating unused spectrum bands
- 3GPP Rel 12: Carrier Aggregation

Efficiently using less congested proprietary spectrum bands: Spectrum Sharing
- Spectrum Sharing

Sharing bands in Unlicensed Spectrum
- 3GPP Rel 12: Carrier Aggregation
- Economic value in US $49.78 billion of the annual GDP

✓ Military / defense bands
✓ TV bands

Spectrum Sharing:
- Two or more technologies utilize the same range of spectrum bands
- Chunks of unutilized or little utilized spectrum frequencies can be shared in a cooperative way
- Effective utilization of spectrum

ICACC 2016
Spectrum Sharing in Unlicensed Bands

Licensed Spectrum
- **✓** Operator-controlled
- **✓** Sole ownership
- **✓** Customizable Deployment
- **✓** Little / No Interference

Unlicensed Spectrum
- **×** Hugely Expensive
- **×** Hardly available
- **✓** Available
- **✓** Not Overtly Congested
- **✓** Free to Use

Classification of Unlicensed Spectrum Bands
- Higher Spectrum (> 6 GHz):
  - **✓** More Frequency Reuse & Less Interference
  - **✓** Energy Efficient & Higher data rates
  - **×** Less Penetration abilities
  - **×** Complex Hardware; Costly

- Medium Spectrum (3.5 - 6 GHz):
  - **✓** Less Interference
  - **✓** More Spectrum Reuse
  - **×** Limited Coverage
  - **×** Needs More Small Cells
  - **×** Coexistence Problem

- Lower Spectrum (< 3.5 GHz):
  - **✓** Less Spectrally Demanding
  - **✓** Wide Area & Low Power
  - **×** More Interference

5 GHz; < 1 GHz; 60 GHz (mmWave)
Recent Initiatives in 5 GHz Unlicensed Spectrum

- **LTE-Unlicensed (LTE-U):** LTE in the Unlicensed Spectrum (5 GHz band; 5150-5925 MHz)
  - By Qualcomm in 2013; Pre-standard proprietary version backed by LTE-U Forum

- **Licensed Assisted Access (LAA):** 3GPP standardization version (5 GHz band)
  - Part of ongoing Release 13 (Down Link); Completion: 2016

- **Enhanced LAA (eLAA):** 3GPP standardization version
  - Part of future Release 14 (Down Link and Up Link); Expected Completion: 2017

- **LTE-WLAN Aggregation (LWA):** 3GPP standardization version
  - Part of ongoing Release 13; Completion: 2016

- **MultiPath (TCP) Aggregation (MPTCP):** Standardized by IETF (Commercialization underway)

- **MulteFire:** Will be standardized by MulteFire Alliance (based on 3GPP standards)
  - Expected completion of technical specifications: End of 2016
Aggregation of LTE transmission in licensed and unlicensed bands using Carrier Aggregation (CA)

- **Advantages:**
  - Greater data capacity
  - Faster download speeds → as simultaneous data transmission over both licensed and unlicensed spectrum
  - Easy bundling of LTE-U with existing LTE carriers in licensed spectrum

LTE transmission in licensed band would expand into the unlicensed bands to increase size of available DL channel

- **LTE Primary Carrier**
  - Licensed Spectrum
  - Anchor Carrier UL/DL
  - Control and signaling
  - Mobility

- **LTE Secondary Carrier**
  - Unlicensed Spectrum
  - LTE-U SDL
  - Speed boost
LTE-Unlicensed and Licensed Assisted Access

- **LAA → Listen-Before-Talk or LBT** (regulatory requirement in unlicensed bands to check whether channel is free before talking; part of 3GPP Rel 13 standard)

- **LTE-U → Carrier Sensing Adaptive Transmission or CSAT** (non-regulatory and on-off duty-cycling based; part of 3GPP Rel 10-12 standards)

- Sensing time → Clear Channel Assessment period
- LBT is mandatory in Europe, Japan and others

- Sense channel utilization; random duty-cycling
- Non-LBT markets, e.g., USA, China, India, Korea etc
LTE-WLAN Aggregation and MulteFire

- No need for LTE-U 5 GHz hardware as LTE packets will use WiFi APs

LAA (Rel 13)  
eLAA (Rel 14)

MulteFire

- Only LTE Unlicensed technology operating fully in the unlicensed spectrum (5 GHz globally; also 3.5 GHz in USA)

- Support for both LTE Up Link and Down Link in Unlicensed Spectrum (Listen-Before-Talk technology)

- No need of an anchor carrier in the Licensed spectrum

- LTE packets are transmitted using Wi-Fi Access Points in Unlicensed Spectrum
LTE and Wi-Fi: Coexistence in the Unlicensed Bands

- WiFi operators not happy with the sharing and fear that WiFi performance will suffer
- LTU-U Forum (Ericsson, Qualcomm, Samsung, Verizon etc.):
  - Spectrum Sharing will not impact Wi-Fi services

• Concerns?
  - WiFi performance in presence of LTE
  - Interference will be significant
  - Cellular technology in unlicensed bands → “Unethical”
Challenges: Technical

• ‘Listen-before-Talk’ (LBT) requirements – how much will LTE-U implement? Novel coexistence mechanisms needs to be devised for ‘fair sharing’ of unlicensed bands.

• LTE-U’s duty-cycling may reduce Wi-Fi throughput and increase latency. How to solve this?

• Periodic beacons from Wi-Fi can be affected and it may increase power consumption of Wi-Fi clients. Also WiFi voice and video may suffer.

• How may LTE-U’s channel selection process interact with automatic channel selection algorithms in deployed Wi-Fi equipment? Smart selection of channels is very crucial to avoid interference.

• How to provide quality-of-service for LTE traffic on the unreliable unlicensed bands
Challenges: Non-Technical

• What policies are there to govern such “fair” sharing/use of spectrum?

• Unlicensed bands can be overused by operators → how may this be monitored and regulated?

• LTE-U may dominate over (even push out) Wi-Fi → How to monitor and regulate that “technology behaviour” in the unlicensed spectrum?

• Will the Governments in different countries encourage such sharing of unlicensed spectrum?
Effects of Unlicensed Spectrum Sharing on WiFi

- **Field Testing and Simulations results:**

  ✓ Wi-Fi performance is not degraded in presence of LTE-U

  ✓ Significant throughput gain can be achieved because of LTE licensed and unlicensed band aggregation

  ✓ Interference effect on Wi-Fi from LTE-U is similar to that between Wi-Fi-Wi-Fi

  ✓ LAA network can reach higher capacity than a WiFi network

  ✓ LTE-U relies on LTE core network => changes in core network domain not needed while deploying
IoT Initiatives in Unlicensed Spectrum

• By 2022: Expected more than 360 million IoT connections

• Different applications have different service requirements: excellent and ubiquitous coverage, ultra-low power operations, adequate bandwidth, secured and low-cost communication etc.

• Cellular technologies (e.g., LTE, WiMAX, HSPA etc.) cannot meet these requirements (high cost, low battery life etc.); WiFi, Zigbee, Bluetooth are short-ranged.

• Spectrum allocation needs to be application-specific and must satisfy service requirements → A Huge Challenge to Meet!!

IoT Initiatives in Unlicensed Spectrum

- **Requirements?**
  - Wide-area non-expensive machine communication network
  - Should be open global standard and not proprietary
  - Globally harmonized low-frequency spectrum
  - Spectrum should be of low cost and needs to be plentiful

Globally **harmonized low-frequency spectrum in unlicensed bands** can be made available for IoT → e.g., below 1 GHz like 870-876 MHz and 915-921 MHz; 700 MHz and TV White Spaces

- **IoT Low-Power Wide Area Network (LPWAN) technologies** in unlicensed spectrum:
  - **SigFox** → European company providing separate IoT network; 868 MHz in Europe, 900 MHz in USA
  - **LoRA (Long Range)** → European company; similar frequency bands
  - **Ingenu** → provides higher data throughout rates than LoRa and SigFox; operates in 2.4 GHz bands, so has shorter range
IoT Challenges in Unlicensed Spectrum

• Can we have worldwide default (preferably) unlicensed spectrum allocation for IoT connections? E.g., 915 – 928 MHz bands?

• Can IoT devices self-understand which country they are operating in and self-switch to allocated IoT spectrum bands there?

• An universally accepted LPWAN standard needed for M2M/IoT connections worldwide.
  ✓ 3GPP is pursuing standardization of 3GG-based IoT technologies, but what about others?

• How will interference between different wide-ranged LPWAN technologies be handled?
IoT Challenges in Unlicensed Spectrum

• Multiple technologies use unlicensed spectrum in an uncoordinated manner. How transmission of data may be affected?

• Power-restrictions may reduce interference but will affect the wide-range of transmission. This is a trade-off!

• How can there be ‘fair sharing’ of the unlicensed spectrum between IoT technologies?
Conclusions

• Telecommunication and networking fraternity eagerly waiting to know what 5G will offer.

• 2020 vision → massive explosion of mobile traffic owing to huge number of connected devices, new services and use cases.

• More spectrum is required; spectrum sharing in unlicensed spectrum is the key.

• LTE plans to expand in 5 GHz unlicensed bands; coexistence with WiFi is an issue.

• Low power and wide-area IoT technologies are trying to use unlicensed spectrum.

• Cooperation, coexistence and fair sharing of unlicensed spectrum is important; worldwide harmonized and regulated unlicensed spectrum allocation approach is needed.
Thank You..

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