Evolução de redes celulares para 5G e convivência entre sistemas na mesma faixa do espectro

Seminário Gestão de Espectro - uma visão de futuro
ANATEL, 30 de Abril de 2015

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Agenda

- Wireless Research @ INDT
- 5G
- LTE / Wi-Fi Coexistence
  - Problem Overview
  - Mechanisms
- Final Remarks
Non-profit R&D Center
founded in 2001

Focused on solutions
in the mobile technology area

Highly qualified technical team
of 200+

Located in Brazil
- Manaus
- Brasilia
- Recife
- São Paulo

50+ invention reports accepted by Nokia/Microsoft to file patent application

300+ Completed Projects

500+ items of scientific production
Standardization Activities and Competences

- GERAN
  - 2009-2010: Contributions to the standard (OSC topic)

- WIMAX
  - 2005-2009: Proprietary feature performance for 802.16e product
  - 2009-2010: Contributions to 802.16m standard

- IETF
  - 2010: IP mobility and IPv6 transition RFCs and Prototypes
  - 2010-2011: Implement the IP Flow Mobility on top of DSMIPv6

- CEPT
  - 2010-2011: TVWS Regulatory contributions
  - 2013: LTE 700MHz Regulatory contributions

- Wi-Fi
  - 2012: Coexistence between Wi-Fi and LTE (IPR generation).
  - 2013: HEW (IPR generation)
  - 2013/2014: 802.11ax technical contributions and evaluation
  - 2013/2014: Implement and test Hot Spot 2.0 connectivity mechanism

Core Competences

- STANDARDIZATION (3GPP & IEEE)
- DIGITAL SIGNAL PROCESSING
- RADIO RESOURCE MANAGEMENT
- MULTI-ACCESS TECHNIQUES
- MULTI ANTENNAS TECHNIQUES
- MULTI- CARRIER
- RF PROPAGATION
- WIRELESS SIMULATION TOOLS
- SDR/FPGA/DSP PLATFORMS
Problem Overview

- Global mobile data traffic grew 69% in 2014
- Forecast for 2015-2019
  - Smartphones: 3/4 of mobile traffic by 2019.
  - 4G traffic: > 50% of mobile traffic by 2017.
  - More traffic will be offloaded from cellular networks (e.g. to Wi-Fi) than remains on cellular networks by 2016.
- Data Tsunami is coming

Why not 4G?

### Reasons

**Not enough capacity for expected connectivity needs**
- Improved spectral efficiency needed
- Huge differences in data rate remain between hotspot and rural deployment

**No good enough support for local area with 3GPP technology**
- Drawbacks from current femto cell solutions
  - Scalability and flexibility issues, due to heavy core network involvement and burden
  - Need for additional Interference control functions

**Cloud Computing**
- Computing is moving from costly equipment with high processing power (desktops and notebooks) to small tetherless cheap devices (smartphones/tablet)
- Intelligence and processing is moving towards the network centre (cloud)
- Traffic between end-user devices and network increases substantially
### Why not 4G?

#### Reasons

<table>
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<tr>
<th>No native support for machine communications</th>
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<td>- Internet of things will require communications between large number of autonomous devices</td>
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<td>- Insufficient support for very large number of devices</td>
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<td>- No sufficient support for large number of (always-on) devices</td>
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<td>- Machine communications have different requirements:</td>
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<td>- Low power consumption</td>
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<td>- Bursty transmission – short packets</td>
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<td>- Technologies must scale</td>
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<table>
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<th>Data rate is not the only requirement!</th>
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<td>- Very low latency requirements (&lt;1ms) for some emerging applications:</td>
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<td>- Haptic control / tactile internet</td>
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<td>- Critical communications, e.g. Autonomous vehicles</td>
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5G Scenarios: Metis 2020

Works in a crowd
- Great experience even in extremely crowded situation
- Extreme traffic densities
- Ex: Shopping Mall, stadium, open air festival

Ubiquitous things Communication
- Very large number of small, simple and inexpensive devices.
- Requirement for long battery lifetime, scalability and adaptability

Mobility: Best Experience follow you
- Same experience at home, in the office or on moving
- Intelligent Vehicular
- Robust communication

Super Real-Time and Reliable Connections
- Low E2E latency delay and Reliable communications enabling critical M2M applications
- Traffic Efficiency and Safety

Amazing end-user experience
- Rate higher than 1Gbps

Amazingly Fast
Disruptive Technologies Directions

- What Technologies will define 5G?
  - Potential disruptive Technologies could lead to both architectural and component design changes
- 5G will be just an evolution of 4G?
  - No! Towards Network Efficiency!

Node

- Evolution in design (Minor Changes)
- Components Changes (Disruptive Changes)

Architecture

- Evolution in design (Minor Changes)
- Architecture Changes (Disruptive Changes)
5G Drivers: Disruptive Technologies

- **Device Centric Architectures**
  - Strong Tendency: Disruption of Cell Centric Structure
  - Why? Different trends...
    - Network Densification
      - BTS with vastly different powers and coverage areas (HetNets, Small cells)
      - Multiple RAT with Control and Data Planes in separated nodes
    - Additional Spectrum
      - Coexistence of frequency bands within in the same system (and vice-versa)
      - Very large bandwidths for Gbps transmission
    - Internet of Things
    - Smarter Device
      - D2D and Smart Caching requires new architecture: Center of Gravity moves from the network core to the periphery
    - Cloud Ran: advanced Centralized Baseband processing
      - Save operational cost
5G Drivers: Disruptive Technologies

• Smarter Devices: devices will play a more active role
  • D2D: co-locate devices could wirelessly share content without the use of base stations or the core network
  • Local Caching: Mobile phone with vast amount of memory
    • Local caching of content and other techniques to enhance the user experience

• M2M - Native
  • M2M means a massive number of connected devices
  • Each connected machine transmits small data blocks sporadically
  • Requirements:
    • New network that support massive connections
    • Very high link reliability
    • Low latency and real time operation
5G Drivers: What else is needed?

• New Physical Layer
  • Current 4G Physical Layer is not flexible enough
    • Focus on cellular wireless broadband
  • 5G Physical Layer needs:
    • Support for heterogeneous types of users:
      • Wireless broadband access and Low-rate machine-type communications
      • Long range / short range and Local traffic / long-haul traffic
      • Energy-efficient and Critical communications
    • Operation in very dense asynchronous scenarios
      • Very high interference without coordination / synchronization among transmitters
  • New Waveforms and Coding are needed

• Massive MIMO
  • A very large antenna array at each base station
  • Benefits from the (many) excess antennas
    • Large number of users are served simultaneously
    • Simplified multiuser processing
    • Reduced transmit power
    • Very narrow beams are possible
  • Key technology for Millimeter Wave
**5G Drivers: Disruptive Technologies**

- **Millimeter Wave Communication**
  - Available UHF Cellular Spectrum is around 600MHz (not enough)
    - Refarm Spectrum
    - Cognitive Concepts (TVWS, ASA, LSA)
  - mmWave and cmWave: a huge amount of spectrum
    - 3-300GHz
      - Potential ranges: 28-30GHz, 60GHz, 81-86GHz and 92-95GHz
- **Some Challenges**
  - Propagation and Antennas Array issues
  - Protocols to manage beam directions
  - Hardware Issues: High Power consumptions of (ADCs/ DACs)

- **Visible Light Communications**
  - between 430 and 790 THz
  - Cheap and widely available components (LEDs and photodetectors)
  - Short range, but Little interference
Centimeter Wave Measurements - 24 GHz
LTE/Wi-Fi Coexistence

- Problem Overview
- Challenges for LTE / Wi-Fi Coexistence
Problem Overview

Q: How to cope with increasing demand for traffic and decreasing revenues per user?

A: Mobile Traffic Offloading
Are there *cheap* spectrum portions to attend demand?
- Unlicensed spectrum (e.g. ISM bands @ 2.4 GHz and 5 GHz)

Which wireless technology to use?
- 4G (LTE Rel10 and beyond)
  - OFDMA-based (i.e. multiple UEs at the same time) and Contention-Free
  - Higher efficiency, but higher cost
- Wi-Fi (802.11ac and beyond)
  - OFDM-based (i.e. single STA at any time) and Contention-Based
  - Lower efficiency, but lower cost

How would LTE and Wi-Fi coexist in unlicensed spectrum?
Challenges for LTE / Wi-Fi Coexistence

- **Main issues**
  - LTE is contention-free, while Wi-Fi is contention-based
    - Wi-Fi “listens” before transmitting, LTE simply transmits
  - Wi-Fi has fixed TX power, while LTE has Power Control
    - Different ranges & interference management
  - Different bandwidth
    - LTE varies from 1.5 MHz to 20 MHz (aggregate up to 100 MHz), while Wi-Fi has fixed 20 MHz (aggregate up to 160 MHz)
  - LTE and Wi-Fi cannot exchange signaling
    - No common control channel
MCETV Project (2012)

- **Mobile Coexistence Enablers for TV Whitespace (MCETV)**
  - Joint research with Nokia Research Center (NRC) in Berkeley, USA

- **Objectives**
  - Evaluate LTE and Wi-Fi performance while coexisting in the same unlicensed spectrum
  - Propose enhancements to enable coexistence of both systems

- **Team**
  - INDT: André Cavalcante, Erika Almeida, Fabiano Chaves, Fuad Abinader, Rafael Paiva
  - NRC Berkeley: Klaus Doppler, Sayantan Choudhury, Esa Tuomaala
Guiding Questions:
- Wi-Fi is likely to be blocked by LTE due to carrier sense, but how much?
- What could be done to alleviate that?
- And to what extent these solutions help to mitigate coexistence issues?

Evaluation Methodology
- Link-level and System-level simulation evaluation
LTE performance is slightly affected by coexistence with Wi-Fi => T-put reduction ≈ 0 %

Wi-Fi performance is severely degraded by coexistence with LTE => T-put reduction ≈ 80 %
## LTE / Wi-Fi Coexistence Solutions (2012)

- **Solution 1: LTE Blank Subframes**
  - LTE “silences” for Wi-Fi operation
  - LTE/Wi-Fi Common Preamble for Synchronization

- **Solution 2: LTE UL TX Power Control**
  - Old TX Power control algorithm
    \[
    P(i) = \min \{ P_{\text{max}}(i), P_{\text{OL}}(i) + P_{\text{CL}}(i) \}
    \]
  - New TX Power control algorithm
    \[
    P_{\text{OP}}(i) = P_{\text{OL}}(i) + \alpha(j) \cdot 10 \log_{10} \left( \frac{\beta \cdot 10^{I_{d}T/10} + 1}{10^{I_{d}T/10} + 1} \right)
    \]
LTE / Wi-Fi Coexistence Solutions (2012)

- Simulation Results
  - Both approaches are able to define different trade-off configurations for LTE/Wi-Fi coexistence
  - LTE Tx Power Control seems more flexible, but LTE Blank Subframes allow Wi-Fi synchronization
Observations

- LTE outperforms Wi-Fi in similar scenarios for stand-alone operation
- LTE performance in coexistence with Wi-Fi is nearly unchanged
- Wi-Fi performance is degraded when it operates concurrently with LTE

Enabling solutions for LTE/Wi-Fi coexistence are able to set different configurations

- Flexibility in defining a trade-off between LTE and Wi-Fi performance
Project Outcomes

4 papers
- Cavalcante et al., *Performance Evaluation of LTE and Wi-Fi Coexistence in Unlicensed Bands*, IEEE VTC Spring 2013
- Almeida et al., *Enabling LTE/WiFi coexistence by LTE blank subframe allocation*, IEEE ICC 2013
- Chaves et al., *LTE UL Power Control for the Improvement of LTE/Wi-Fi Coexistence*, IEEE VTC Fall 2013

3 pending patents
- Kim et al., *Null Subframe Indication for Coexistence Between Different Network Types*, WO 2014051606
- Paiva et al, *Cyclic Prefix Based Opportunistic Transmission/Reception Scheme for Interference Cancellation*, US20140301282 A1

1 national innovation prize
- 2nd place on the “Software / Service Provider” from Anuario Tele.Sintese 2013
Final Remarks

- 5G
- Input to IEEE 802.11 HEW SG / Tgax
- Further Developments
Challenges to Regulation

• New Spectrum
  ✔ Very high data rates will require very large bandwidths (>200MHz)
  ✔ New bands must be reserved (possibly in place of existing services)
    – cmWave – below 6GHz
    – mmWave – above 6GHz

• Coexistence
  ✔ Many new players beyond large network operators
  ✔ Increased use of unlicensed spectrum (with different Technologies)
    – Sharing rules are needed

• New Services
  ✔ With very different requirements
    – E.g., intervehicular communications x video downstreaming
    – Is network neutrality desirable/possible in this scenario?

- ITU is starting discussion on IMT-2020 at World Radiocommunications Conference in Nov 2015
Further Developments

3GPP is foreseeing LTE in Unlicensed Spectrum (LTE-U) as “an important complement to meet future traffic demand” [1], with focus on 5GHz


Wi-Fi Alliance® is aware of 3GPP work addressing LTE operation in the unlicensed 5 GHz band, .... There is a risk that LAA, and especially pre-standard systems deployed ahead of coexistence work being done in the industry, will negatively impact billions of Wi-Fi users who rely on 5 GHz today for networking and device connectivity. [2]

Further Developments


- Qualcomm demonstrated a complete solution, including multi-RAT mobile chipset, in Mobile World Congress 2015 (MWC`15).

- Wi-Fi Alliance (WFA) launched a Coexistence Task Group (Coex TG) on March 2015 to further evaluate LTE-U coexistence and provide guidance to 3GPP on how to refine LTE-U coexistence.
Thanks!

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