Overview of 5G Research @ IITH

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More than 50 Billion Connected Devices

- More than 50 Billion sensorized connected devices by 2020
  - Proliferation of Smart phones, Machine-to-Machine (M2M), Internet of Things (IoT)
  - Serving Multiple Applications over Multiple Networks
  - Convergence between Cellular, sensors, M2M/IoT
  - Networked society
    - Wireless sensors – smart cities

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Requirements

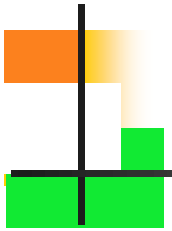
- User requirements
  - Always connected to the **cloud**
  - Uniform experience independent of user location
    - variation in data rates 100Kbps to 1Mbps– even in 4G
  - 5G should offer 100-1000x increase in data rates
  - Ultra **low latencies**
- Network requirements
  - Reduce cost/bit – **Maximize** bits/sec/Hz
  - Reduce Energy/bit – **Energy** efficiency

ITU Future Technology Trends for 5G

- Working Party 5D Document 5D/441
  - Massive MIMO
  - Small Cells
  - Support for M2M and IoT
  - Cloud RAN
  - Tight Integration between WLAN and LTE
    - LTE operation in unlicensed spectrum (LTE-U)
  - Millimeter waves

5G research @IITH

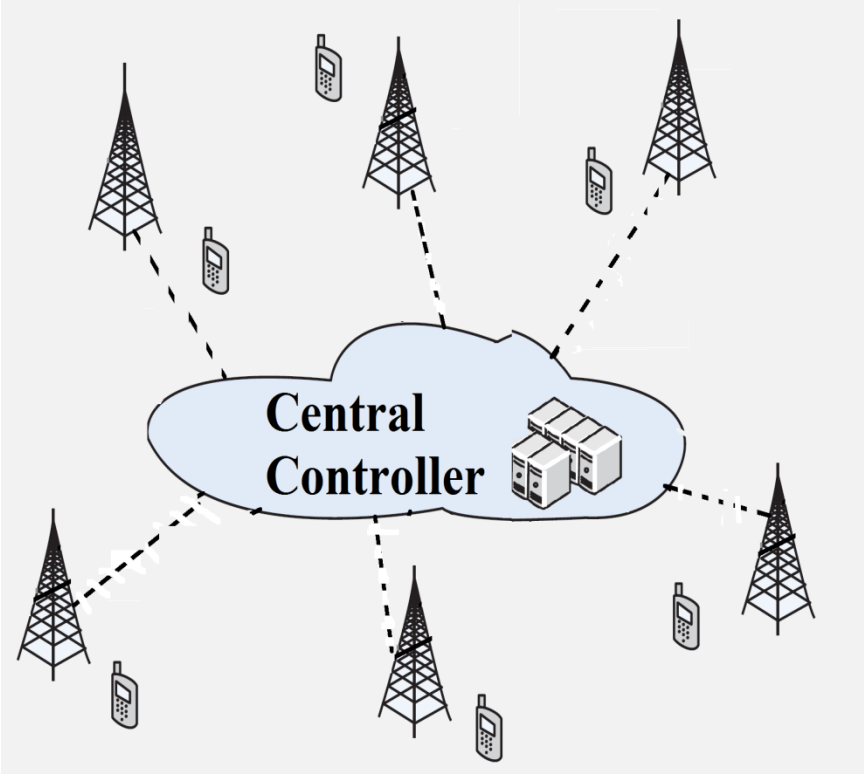
- Cloud RAN
- Waveform Design for 5G
- Licensed Assisted Access (LAA)
  - LTE operation in unlicensed bands
- TV whitespaces
- Massive MIMO and Millimeter waves
- IoT chip design
- Contributions to TSDSI (Telecommunications Standards Development Society, India)



Cloud RAN

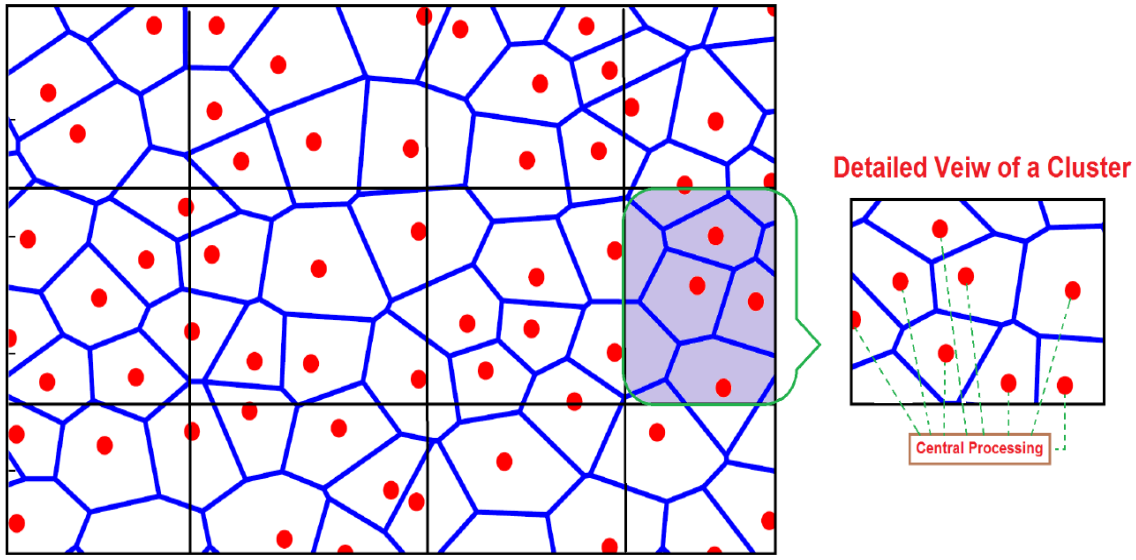
CRAN Architecture

- 3GPP LTE introduced COMP
- BSs are connected to a central unit (cloud) through fiber to remote radio head-ends (RRH) using CPRI protocol
- Baseband signal processing and scheduling at the cloud
  - Interference mitigation
  - Load balancing through scheduling



CRAN Clustering

- In real life, the size of the cloud is limited
- Cluster: Groups of BSs are connected to a central processor
- Cloud processing is applied in each cluster independently
- Cluster edge users interference will be high



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Status of CRAN prototype

- Tejas Networks, an Indian telecom vendor supplied commercial grade BS hardware with RRHs
- Centralized BS implemented using TI multi-core DSP processors
- UE implemented using same BS quality hardware
- Baseline: LTE
- Additional enhancements
  - Network MIMO operation: Non-linear Tomilson-Harashama precoding (THP)
  - Feedback of neighbouring channel states from UE
- The prototype would implement clusters of BSs where cooperation is applied in each cluster
  - Cluster size: approx 10 BS; Inter-cluster interference effects will be captured
- First filed trial in 6-months

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LTE Operation in Unlicensed Bands

LTE unlicensed

- Licensed spectrum remains 3GPP operators' top priority to deliver advanced services and user experience
- Opportunistic use of unlicensed spectrum is becoming an important complement for operators to meet the growing traffic demand
- Moving forward 3GPP operators will have two options to offload traffic to unlicensed spectrum:
  - Wi-Fi (via LTE/Wi-Fi interworking)
  - LTE over unlicensed
- It will be up to individual operator to choose which approach to use, which will depend on a number of factors

Source: http://www.3gpp.org/ftp/Information/presentations/presentations_2015/2015_01_3GPP_unlicensed_Dino_Flore.pdf

LTE-WiFi interworking

- Framework being developed since the first release of LTE-8
  - With tighter and tighter forms of interworking added in subsequent releases
- New proposal for even tighter radio-level interworking are currently being evaluated for Rel-13, including:
  - LTE/Wi-Fi aggregation
  - Enhanced network controlled mobility, via enhanced UE measurement reporting and network steering capabilities
  - Interface between LTE eNBs and Wi-Fi APs

LTE over unlicensed

- The discussion was kicked off by a workshop in Jun. 2014 which established the initial priorities (RWS-140029):
  - **5 GHz band**
  - Global solution that can work across regions
  - Licensed-Assisted Access (LAA) operation
    - Aggregation of a primary cell, operating in licensed spectrum to deliver critical information and guaranteed Quality of Service, with a secondary cell, operating in unlicensed spectrum to opportunistically boost data rate
    - The secondary cell operating in unlicensed spectrum can be configured either as downlink-only cell or contain both uplink and downlink
  - Fair coexistence between LTE and Wi-Fi as well as between LTE operators

Licensed-Assisted Access (LAA)

- The feature is targeting completion in Rel-13, which is scheduled to freeze in Mar. 2016
- Item (SI) was approved by RAN in Sep. 2014 and is scheduled to complete in Jun. 2015
  - Main SI goal: study the LTE enhancements needed to operate in unlicensed spectrum and to ensure fair coexistence with Wi-Fi
- The detailed SI description is available in RP-141817

One US operator is going to launch pre-rel-13 LTE-LAA products. There is strong support for LTE-LAA feature from some major European operators as well

LAA-LTE: Design Targets and Functionalities

- Agreed design targets:
  - Single global solution allowing compliance with any regional regulatory requirements
  - Effective and fair coexistence with Wi-Fi
  - Effective and fair coexistence among LAA networks deployed by different operators

- Based on the above targets, it was agreed that at least the following functionalities are required for LAA:
  - ***Listen-before-talk*** (Clear channel assessment)
  - Discontinuous transmission on a carrier with limited maximum transmission duration
  - *Dynamic Frequency Selection* for radar avoidance in certain bands/regions
  - Carrier selection
  - *Transmit Power Control*
- On fair coexistence with Wi-Fi
  - Initial qualitative definition provided in the SI description:*[…] LAA should not impact Wi-Fi services (data, video and voice services) more than an additional Wi-Fi network on the same carrier; these metrics could include throughput, latency, jitter etc. […]*
  - Exact metrics to be defined in the coexistence study

Present Status in 3GPP

- Presently Wi-Fi and LAA-LTE do not currently use a common media access mechanism that would implicitly result in fair sharing
- 3GPP presently uses media sharing mechanisms defined in **ETSI 301 893** which is the basis of compliance regulations for the 5GHz band in Europe

LTE-LAA Operational Scenarios

- In LTE-LAA channel reservation is done at the base station
  - Multiple User equipments (UEs) are served by the BS in scheduled mode
  - **Option-1**: LTE-LAA operates in down link (DL) only mode; Uplink (UL) date is carried in the licensed carrier
  - **Option-2**: LTE-LAA operates in both DL and UL
    - UL in scheduled mode; user transmits only if interference is below a threshold; channel reservation procedure is not applied by LTE-LAA UE in UL

Channel access mechanisms considered in 3GPP

- LTE-LAA study item considers Listen Before Talk (LBT) with **fixed back-off window** (as defined in ETSI 301 893)
  - Works well under low load and light interference
  - Enhanced channel access mechanisms may be considered during specification phase
- WiFi uses CSMA with **exponential back-off**
  - Designed to handle high system load and adverse interference conditions
- LTE-LAA is expected to study the use of variable back-off window during the subsequent study phases

Problem Statement

- In LTE-LAA study, channel reservation is done at the base station
- A new mechanism needs to be introduced to increase channel reservation time of LTE-LAA BS and yet ensure fairness to WiFi

Waveform Design for 5G

5G Waveform Design

- In addition to providing high data rates 5G expected to enable new applications with
  - ultra-low latency
  - low power consumption
- Limitation of OFDM and LTE
  - High out-of-band emissions
  - Tight synchronization requirements in LTE
  - High PAPR
- 5G expected to introduce a new waveform to support low-latency applications

Candidate Waveforms

- FBMC (Filter band multicarrier)
- GFDM (Generalized frequency division multiplexing)
  - A variant of DFT-precoded-OFDM (SC-FDMA)
  - Allows self-interference between users for increasing spectrum efficiency
  - Low PAPR compared to OFDM
  - Low OBB
  - Short TTI (transmission time interval): low latency
- Need to develop GFDM like waveforms with very low PAPR and OBB
  - Other alternatives being investigated at IITH

Other activities

Other activities

- Cognitive Radio
  - TV whitespaces
- Massive MIMO and millimetre waves
  - Massive MIMO in LTE
  - Massive MIMO in mm waves
- IoT chipset design

Telecommunications Standards Development Society, India (TSDSI)

TSDSI

- Indian SDO backed by Govt of India
- Responsibilities include: Development of technical specifications, advise Govt on policy and regulation, liaison with external SDOs
- Members include telecom operators, vendors, academia, Govt bodies
- Operational for over a year
- IITH contributions active contributor TSDSI

Summary

- IITH to contribute to research, prototype development, and standardization in 5G
  - Emphasis on IPR and product development
- IITH to develop a smart city prototype at the new campus
  - Wireless sensor networks
  - Smart grid

Thank you!