Intelligent connectivity enablers for converged heterogeneous 5G-IoT ecosystem

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Major Challenges of Today

• **Increased** mobile data **traffic**, some say **1000x and beyond**
• **Growth in connected devices**, up to 50 billion devices
• **Diverse requirements and characteristics**

Current mobile networks are likely to face **capacity crunch**

Attention shifts to **what comes beyond 4G** (Fifth Generation!)
Wireless Data Traffic

New forecasts are orders of magnitude higher!

Source: Report ITU-R M.2243
What is on the Horizon 2020

• Given a 10-year cycle for every existing generation, we expect 5G systems sometime around 2020
• Whereas there is currently no complete definition, 5G may already be understood from the user perspective

Human users would like to be connected at all times
• regardless of their current location
• take advantage of services provided by multimedia-over-wireless networks
A Glimpse of Tomorrow

Main challenge: user’s **connectivity experience should match service rate requirements and be uniform**

The “Big Three” 5G Technologies:
- ultra-densification
- mmWave radios
- massive MIMO

Source: Intel @ Globecom 2014
Re-Purposing Wireless Spectrum

LSA = Licensed Shared Access

An emerging concept for spectrum sharing under an **exclusive** license regime
Intelligent Use of Multiple Radio Access Technologies (RATs)

HetNet = multi-tier + multi-RAT

Licensed spectrum continues to be scarce and expensive
Radio Access Network (RAN) Selection

The incentive to efficiently coordinate between the alternative radio access technologies is growing stronger.
3GPP/WLAN Integration Options

WLAN becomes an integral part of wireless landscape

- **Application** layer integration
- **Core network** based integration (e.g., ANDSF): LTE Release 11
- **RAN** based integration: LTE Release 12, contd. in Release 13

**Friends or Foes?**
Proof-of-Concept Demonstration

RAN-assisted link selection creates significant improvement in mobile user experience by enabling dynamic traffic-aware transmission.

An important extension is link aggregation for integrated WLAN/3GPP cells.
Coordinated Radio Resource Management

**Heterogeneous cloud radio access networks enable cooperative radio resource management**
Towards Extreme Network Densification

Integrated ultra-dense HetNet is an unprecedented paradigm shift.
Harnessing Very High Frequencies

mmWave spectrum should be 10–100 \times \textbf{cheaper per Hz} than the 3G and 4G spectrum below 3 GHz

Source: NYU-Poly
Capable Mobile Devices

Industry’s concept of mobile performance is evolving, and so are performance metrics

Source: Intel Corp.
Device-to-Device (D2D) Communications

Significant operator and end user **benefits** by enabling a new generation of **proximity services**

a. 3GPP LTE assistance
LTE-Assisted WiFi-Direct

Improved D2D connection establishment, battery efficiency, and service continuity on the system-wide scale.
Production-Ready D2D Prototype

Automated, continuous, and efficient **assistance** with secure discovery of devices & services

Devices **receive help** from the network during device discovery and D2D connection establishment

**Test 3GPP LTE deployment:**
D2D-based Coding and Caching

Need to understand the potential of network coding and user-centric data caching to upgrade assisted proximate communication

New models are required to investigate dynamic mobile content behavior
Mobile User QoS/QoE Estimation

There is a growing demand for adequate QoE estimation models accounting for dominant mobile data services (HTTP, YouTube, etc.)
Multi-Radio Energy Awareness

Concentrate attention on **energy efficiency** of a mobile device:

- Optimize Tx power per radio
- Recommend when each RAT should be used
Wearable Communication Technology

Wearable wireless devices are very likely to soon move into the mainstream of our society, led by the rapidly expanding multibillion dollar health and fitness markets.

High-density mobile wearable scenario: a commuter train
Diversity of IoT Applications and Services

The world is developing toward a **networked society**, where *all kinds* of devices interact and share information.

Source: Ericsson Research
The IoT
Smart car parking, H2H + M2M, Automation,
Small data, Smart factory, Overload control,
Smart grid, Massive M2M,
Smart agriculture

Vision
Wearables, D2D for M2M, Vehicular,
Smart home,
Rural deployment, Coverage extension,
Commuter train
Long-Range Radio Technologies for MTC

Recent efforts focused on improving 3GPP LTE support of MTC: overload control, small-data access, coverage extension, etc.

Network has to reliably support very large numbers of devices with very low traffic.
Novel Small-Data Access Mechanisms

Additional **data access channels** are necessary in 3GPP LTE to enable **massive** MTC deployments with **stringent** performance requirements, in both idle and connected modes.
Reaching certain locations such as *basements* may be difficult and thus *coverage enhancement* features have been proposed for LTE.
Other Radio Technologies for MTC

**IEEE 802.11ah** technology is currently being developed to empower *low-cost* and *large-scale* connectivity across massive MTC deployments with high spectral and energy efficiencies.

Analysis for up to **10K** devices
Potential of (Wireless) Energy Harvesting

As IoT devices are small-scale and battery-powered, the key challenge is to extend their lifetime without recharging/replacing batteries. Hence, device may harvest RF energy transmitted from the source wirelessly via a dedicated radio interface.
5G Research Roadmap by W.I.N.T.E.R.

Network-assisted device-to-device connectivity & Wearable communications technology

Integrated heterogeneous networks & Ultra-dense networks

Multi-radio connectivity & Power efficiency

Indoor mmWave access technology

Short-range technologies for low-power MTC deployments

Large-scale industry-grade machine-type deployments
Some of Our Recent Publications


