MHRD Scheme on Global Initiative on Academic Network (GIAN)

Research Challenges in Wireless Technologies for 5G

It is well recognized that the need for fast access to information and data forms an integral part of life in the present day "digital world". The availability of "fast, uniform, reliable and cost effective" connectivity anywhere, anytime for (human) users on the move is essential for enabling the ultimate user experience in web browsing and audio & video streaming. Applications around Machine to Machine (M2M) communications and Internet of Things (IoT) are expected to further enhance the user experience by exploiting the very large volumes of data generated by communication "users" such as sensors and actuators. Advances in signal processing, RF communications (including microwaves) and front-haul / backhaul technologies are poised to be significant enablers of this evolution.

As confirmed by multiple white papers published by industrial fora the world over, the foremost requirement of 5G wireless and mobile communication networks is the ability to support transmission speeds of the order of 100s of Mb/sec to 1Gb/sec. Such transmission speeds associated (at times) with very low latency are a must for satisfying the stringent QoE (Quality of Experience) requirements of upcoming applications. The networks of future (towards 2025) would thus be required to cater for an overall 1000x capacity increase in comparison to the systems deployed during the earlier part of the present decade. These objectives will be achieved through the introduction of new technologies both in Radio Access Networks (RAN) and in Core Network (CN). Additionally, judicious combinations of newly designed 5G technologies and enhanced versions of the present 3GPP (LTE Advanced) and IEEE 802.xx family of technologies are expected to prove useful in efficiently meeting the above requirements.

Enhanced MIMO (Multi Input Multi Output) and Large Scale Antenna Systems (or Massive MIMO) are two important PHY layer "capacity/coverage" enhancement technologies. Deployment of hot spots of micro/pico/femto cells using **mm Wave (above 30 GHz) ultra-broad band technologies** would provide multi-fold network capacity extension. An order of magnitude performance enhancement will be achievable through inter-technology **RAN HetNets (Heterogeneous Networks)**. Such networks will be based, e. g, on interworking between LTE-A overlay cells and underlay hotspots using new **mmWave broad band (WiGig)** and/or enhanced IEEE 802.11 technologies. Air interface adaptations required to cater for very high energy efficiency and massively parallel nature of transmissions from **IoT devices** will form an integral part of the 5G design.

Network efficiency improvements would be achievable through grouping of computational resources for different network elements (ref Cloud RAN Architecture). Possibilities of traffic offloading in HetNets and of decoupling of user data and control planes offered by Software Defined Networking (SDN) and Network Function Virtualization (NFV) would provide additional performance advantages. The above functionalities would imply an order of magnitude efficiency improvement in signal processing architectures. The design of RF and microwave sub-assemblies with reduced energy consumption and requirement of flexibility of deployment and operations are additional challenges in this context.

Description of major new RAN technologies for 5G systems and their interaction with

some new core network technologies, will form the main body of the proposed course. Two initial chapters will cover the technology evolution scene (from 2G to 5G) for mobile and wireless communications; the description of requirement specifications for 5G and the definition of different parameters and QoE related criteria respectively. Different technology description chapters will conclude with the mention of unique requirements of 5G for signal processing and RF communications and of other open research and technology challenges.

The proposed course aims to offer a balanced technical content to suit the requirements of experts from both academia and industry. Hands-on exercise work related to the performance evaluation of proposed technologies will be included.

2.0 Objectives

The primary objectives of the course are as follows:

i) Describe the set of key radio interface technologies for 5G
ii) Learn how to match the Performance Metrics and Requirement Specifications for 5G technologies
iii) Explain trade-offs in RF product design impacted by network evolution for 5G
iv) Understand the co-operation mechanisms between international research bodies; funded research programmes and standardisation bodies for 5G.

3.0 Teaching Faculty with allotment of Lectures and Tutorials

1. **Dr. Vinod Kumar (VK): 12 hrs lectures**
2. **Prof Emeriteus Dr. Vishwanath Sinha (Prof Sinha): 3 hrs lectures**

4.0 Course details

4.1 Tentative Duration:

August 28 – Sept 01, 2017 (5 days); 15 hrs lectures over 5 days

4.2 Tentative Lecture Schedule

Day1

Lecture 1: 1.5 hrs: VK

Introduction
- Cellular (Wide Area) and Local Area Networking
- Licensed and License Exempt Bands
- Operator Controlled vs Personal Networks

Wireless Technology Evolution Scene (Part 1)
- From 2G to 4G+ in Cellular Networking
- From IEEE 802.11b to IEEE 802.11n; ah etc

Lecture 2: 1.5 hrs: VK

Wireless Technology Evolution Scene (Part 2)
- From IEEE 802.11b to IEEE 802.11n; ah etc
- Other technologies of interest - Bluetooth; IEEE 802.15.4

Requirement Definition and Standardization for 5G
- Service and Application Scenarios
- Importance of Vertical Markets
- Technology Research; Business Fora and Standardization Bodies

Back-up

- Basics of Propagation in Mobile Channel

Day 2: 5G Relevant Wireless Network Performance Metrics

Lecture 3: 1.5hrs: VK

Cellular Network Performance Metrics

- Cellular Networking for Optimization of Spectral Efficiency
- Cellular Network Architecture and Basic Functionalities
- Designing for Voice vs Designing for Data and Video

Lecture 4: 1.5hrs: VK

Specific Performance Requirements for 5G

- Coverage and Capacity Duality
- Varied QoE Requirements vs Spectral Efficiency
- 5G pain Points – Spectrum, Deployment Costs and Operator Revenues

Hands-on Exercise No 1

- Calculating Coverage and Capacity of a macro-Cellular BS considering
    - Signal Attenuation and Propagation Models used in Practice
    - Effect of propagation impairments and equipment imperfections on range

Day 3

Lecture 5: 1.5hrs: VK

Advanced MIMO & Massive MIMO (Large Scale Antenna Systems)

State of the Art in (conventional) MIMO

- MIMO for Diversity and Rate Multiplexing
- Comparative Performance vs Complexity Evaluation of MIMO solutions in 4G
- Scalability Limitations and need for enhancement

Large Scale Antenna Systems (LSAS)

- Overcoming the complexity and scalability of existing MIMO solutions
- LSAS Signal Processing Architecture and its Energy Efficiency Advantage
- Solutions for Pilot Contamination Issue
- How Large (Antenna Network) is Large Enough?

Lecture 6: 1.5 hrs: Prof Sinha

Error Correction Coding for Ultrareliable Transmission in 5G - Part 1

- Shannon's promise for reliable communication
- Review of existing FEC schemes

Day 4

Lecture 7: 1.5 hrs: VK

Heterogeneous Networks (HetNets) in 5G

HetNet Architecture and Technology Solutions

- Definitions and Performance Advantages of HetNets
- Comparative Evaluation of Low Tier Technologies
- 5G specific Low Tier Technologies

HetNet Performance Modelling and Optimization

- Stochastic Geometry Techniques for network modelling considering dynamics of UE to BS Association
- Comparative Performance advantages of different association algorithms
- Mobility Management Protocols for traffic-offloading solutions
- Advantages of HetNet and Cloud Networking Synergies

Lecture 8: 1.5 hrs: Prof Sinha
Error Correction Coding for Ultrareliable Transmission in 5G - Part 2
- Suggested alternatives for 5G

Day 5
Lecture 9: 1.5 hr: VK
Very High Bit Rate Coverage in 5G with mmWave Technology
Solution for Spectrum Scarcity
- Availability and usability of > 30GHz spectrum
- Present and Future usage scenarios for point-to-point and cellular coverage
- mmWave Propagation Characteristics

mmWave Technology for Cellular Access
- State of the Art and Future Evolution
- Dynamic Beam Forming and Network Performance Modelling
- Trade-offs for Beam Forming Technologies in LSAS systems

Hands-on Exercises No 2 & 3
- Dimensioning MIMO solutions for enhancement of coverage and capacity for 4G++ networks
- Evaluating the effect of overhead of pilot signals on the spectral efficiency of a 5G Base Station using LSAS with special case of coverage of high speed UEs in mmWave LSAS
- Compensating mmWave path loss with high gain antenna beam forming

Lecture 10: 1 hr: VK
Challenges of Integrating IoT Solutions in 5G
5G and Vertical Markets
- IoT Hype or boon for Vertical Market Solutions
- Standardized vs de facto solutions for cost/performance optimization

5G and the IoT Ecosystem
- Multi-dimensional complexity of standardization in IoT
- Existing vs new (to be designed) protocols for 5G specific applications
- Interaction between 5G standardization bodies and IoT business fora

Hands-on Exercise No 4
- Calculating the reachability of IoT devices for LPWAN's operating in License Exempt bands

Lecture 11: 0.5 hr: Prof Sinha + VK
Global Concluding Highlights and Q&A session

5.0 Who can attend

- Practicing Engineers, Business Executives (Tech) as well as researchers from vendor, operator and government organizations including R&D laboratories.
- Graduate and Post-graduate students (BTech/MSc/MTech/PhD) as well as Faculty from academic institutions and technical institutions.

6.0 Detailed CV of Experts

6.1 CV of Prof V. Sinha: Please refer to the attachments

6.2 CV of Dr V. Kumar: Please refer to the attachments