Basic Principles of Next Generation Networks and Applications.

Jared Baraza, Lecturer Telecoms & IT, Kenyatta University, School of Pure and Applied Sciences, Physics Department

- Website: **www.ku.ac.ke**, Email: jared.baraza@gmail.com, Email: **jared.baraza@ku.ac.ke**,
- Tel: 254 20 810 901-19, Fax: 254-20-811 575, Cell: 254 725 536 699

Basic Principles of Next Generation Networks and Applications.

- Introduction
- Background of mobile wireless technologies
- Building blocks of 3G and 4G
- Standards
- Challenges
- Conclusion

Background of mobile systems

First generation networks:

- Almost all of the systems from this generation were analog systems.
- voice was considered to be the main traffic.
- These systems could often be listened to by third parties.
- some of the standards are NMT, AMPS, Hicap, CDPD, Mobitex, DataTac

Second generation:

- All the standards belonging to this generation are commercial centric and they are digital in form.
- Around 60% of the current market is dominated by European standards.
- The second generation standards are GSM, iDEN, D-AMPS, IS-95, PDC, CSD, PHS, GPRS, HSCSD, WiDEN and CDMA2000 (1xRTT/IS-2000).

2G Networks deficiency

- The 2G networks were built mainly for telephone calls and slow data transmission.
- Due to the rapid changes in technology, these factors do not meet the requirements of today's wireless revolution.
- The developments of so-called "2.5G" (or even 2.75G) technologies such as i-mode data services, camera phones, HSCSD and GPRS have been ways of bridging the oncoming change to **3G** networks, but are not permanent solutions.
- They are merely stepping stones towards the new technology.

2G to 3G Network standardization

- The International Telecommunication Union (ITU) has defined the demands for third generation mobile networks with the IMT-2000 standard.
- An organization called 3GPP has continued that work by defining a mobile system that fulfils the IMT-2000 standard.
- This system is called Universal Mobile Telecommunications System (UMTS). The evolution of the system will move forward with so called releases. In each release new features will be introduced.

3G is **third-generation** technology

- in the context of mobile phone standards. The services associated with 3G provide the ability to transfer simultaneously both voice data (a telephone call) and non-voice data (such as downloading information, exchanging email, and instant messaging). In marketing 3G services, video telephony has often been suggested as the killer application for 3G.

3G Networks

- W-CDMA
  - UMTS (3GSM)
  - FOMA
- TD-CDMA/UMTS-TDD
- 1xEV-DO/IS-856
- TD-SCDMA
- GAN (UMA)
- HSPA
  - HSDPA
  - HSUPA
- HSPA+
- HSOPA

Building blocks for 3G Network

- The UMTS network introduces new network elements that give functionality as given in the 3GPP specifications:
  - Node-B (base station)
  - RNC (Radio Network Controller)
  - MGW (Media Gateway)
- The functionality of MSC and SGSN changes when going to UMTS. In a GSM system the MSC handles all the circuit switched operations like connecting A- and B-subscriber through the network. SGSN handles all the packet switched operations and transfers all the data in the network.
- In UMTS the MGW (Media gateway) will take care of all data transfer in both, circuit and packet switched networks. MSC and SGSN will act as "brains" of the system and they will control MGW operations.
- The name of the nodes will change into MSC-server and GSN-server.

3G challenges

- Even though 3G has successfully been introduced to European and Asian mobile users, there are some issues that are debated by 3G providers and users:
  - High input fees for the 3G service licenses
  - Great differences in the licensing terms
  - Current high debt of many telecommunication companies, making it more of a challenge to build the necessary infrastructure for 3G
  - Member State support to the financially troubled operators
  - Health aspects of the effects of electromagnetic waves
  - Expense of 3G phones
  - Lack of 2G mobile user buy-in for 3G wireless service
  - Lack of coverage because it is still new service
  - High prices of 3G mobile services in some countries,

IMT-2000 radio interfaces

- W-CDMA
- CDMA2000
- CDMA2001
- TD-CDMA / TD-SCDMA
- UWC-136 (often implemented with EDGE)
- DECT

Why the evolution to 3G?

- The Evolution to 3G describes the updating of cellular mobile telecommunications networks around the world to use new **3G** technologies.
  - 3G technologies enable network operators to offer users a wider range of more advanced services,
  - while achieving greater network capacity through improved spectral efficiency.

Beyond 3G-
4G Network research

- 4G
- UMB
- UMTS Revision 8 (LTE)
- WiMAX
- IMT advanced

Requirements for NGN /4G

- Security on the air interface
- Security standards
- High speed
- Optimized data transport
- High QoS standards with support for Laptops, wifi, Wimax, Cellular, RFID…
- Guaranteed quality standards for TV, video, speech, data

NGN Network architecture

- Transport: Optical Transport network (OTN)
- Core Switching: Soft switching
- Edge network: Media gateways
- End user: Routers and servers
- Access Interfaces: ADSL, ADSL2+, VDSL2, SHDSL, POTS, ISDN, Media gateway H.248 & SIP
- Applications and services

Optical Transport Network (OTN)

- OTN is the transport for next generation ITU G.709 spec.
- For multi-service transmission
- Enables connection of different network types and services e.g. SONET, SDH, Ethernet, Video, IP traffic
- Higher bandwidths than SONET/SDH
- Ethernet LAN at 10 Gbps

OTU Hierarchy

- ITU Rec. G.709

OTU-1: 2.7 Gbps
OTU-2: 10.7 Gbps
OTU-3: 43 Gbps

Advantages:

- Efficient multiplexing
- Optimized switching of services
- High bandwidth
- Optimized bandwidth utilization

OTN uses

- Metro- Wavelength Division Multiplexing
  - Used in the inner city metro network
- OED- Optical Edge Devices
  - Used in connecting premises or university campuses
- ON- Optical Networks
  - for connection of clients in the LAN network

Soft switch

- SS is the brain of NGN network
- Functions
  - Real time communication control for voice, data, video, text..
  - Protocol conversion
  - NMS procedures
  - QoS over different network types
  - Triple play

NGN Access platform

xDSL, Copper already on the ground

Triple Play:

- Minimal cost of implementation; Zero loss design
- Integrated support for layer 2
- Integrated Ethernet services capability

- With ADSL2+: 24 Mbps downstream
- With VDSL > 52 Mbps downstream and 16 Mbps upstream
- With Coaxial cable: Wideband for customers upstream 50 Mbps and 10 Mbps downstream

NGN Wireless Access systems

- **IMT Advanced**
  - 3400-5000 MHz candidate band
  - (proposed frequency less than 1 GHz)
  - for HSDPA and HSUPA ,10 Mbps downstream
  - Mobile data maximum 100 Mbps downstream and 50 mbps upstream
- **UMTS-E-Band**
  - 2.6 GHz candidate band
  - OFDMA-downlink and SC-FDMA uplink
  - GPRS support
- **WiFi, WiMax and HiperMAN,** IEEE 802.16 OFDMA

4G Air Interfaces

- Data rates < 100 Mbps for wide area application
- For hot spots: 1 Gbps at a bandwidth of 100 MHz
- Use of multi-carrier antennas
- Need of advanced coding algorithms
- Need for adaptive multi-carrier modulation and coding methods
- Need for cognitive radio systems

Network topologies

- Adhoc and mesh networks
  - No need for network infrastructure
  - Wireless connection between terminal and base station
  - Types:
    - Mobile adhoc- MANET
    - Sensor networks
    - Mesh networks with or without Internet
    - Connectivity
    - Routing
    - Vehicle to vehicle

Cognitive radio

- To eliminate interference problems
- The terminal analyses the situation
- Inbuilt boosting protocol for
  - Distributed reception
  - Boosting stations
  - Interference temperature

NGN services

- VoIP
- Streaming video
- Internet
- SMS
- Video telephony
- Mobility services etc

4G?

- The 4G will be a fully IP-based integrated *system of systems* and *network of networks* achieved after the convergence of wired and wireless networks as well as computer, consumer electronics, communication technology, and several other convergences that will be capable of providing 100 Mbps and 1Gbps, respectively, in outdoor and indoor environments with end-to-end QoS and high security, offering any kind of services anytime, anywhere, at affordable cost and one billing.[1]
- The Wireless World Research Forum (WWRF) defines 4G as a network that operates on Internet technology, combines it with other applications and technologies such as WiFi and WiMAX, and runs at speeds ranging from 100 Mbps (in cell-phone networks) to 1 Gbps (in local WiFi networks).[2] 4G is not just one defined technology or standard, but rather a collection of technologies and protocols to enable the highest throughput, lowest cost wireless network possible.[3]

QOS in 4G Networks

- To cater the quality of service and rate requirements set by the forthcoming applications like wireless broadband access, Multimedia Messaging Service, video chat, mobile TV, High definition TV content, DVB and minimal service like voice and data at anytime and anywhere 4G is being developed , the 4G working groups have defined the following as the objectives of the 4G wireless communication standard
- Spectrally efficient system (in bits/s/Hz and bit/s/Hz/site)[4]
- High network capacity[5]
- Nominal data rate of 100 Mbps at high speeds and 1 Gbps at stationary conditions as defined by the ITU-R[1]
- Data rate of at least 100 Mbps between any two points in the world[1]
- Smooth handoff across heterogeneous network[6]
- Seamless connectivity and global roaming across multiple networks[7]
- High quality of service for next generation multimedia support (real time audio, high speed data, HDTV video content, mobile TV, etc)[7]
- Interoperable with the existing wireless standards[8]
- All IP system, packet switched network[7]
- In summary, the 4G system should dynamically share and utilize the network resource to meet the minimal requirements of all the 4G enabled users.

Motivation for 4G Research

- 3G performance may not be sufficient to meet needs of future high-performance applications like multi-media, full-motion video, wireless teleconferencing. We need a network technology that extends 3G capacity by an order of magnitude.
- There are multiple standards for 3G making it difficult to roam and interoperate across networks. we need global mobility and service portability
- We need wider bandwidth

Motivation cont..

- 3G is based on primarily a wide-area concept. We need hybrid networks that utilize both wireless LAN (hot spot) concept and cell or base-station wide area network design.
- Researchers have come up with spectrally more efficient modulation schemes that can not be retrofitted into 3G infrastructure
- We need all digital packet network that utilizes IP in its fullest form with converged voice and data capability.

Comparing Key Parameters of 4G with 3G

	3G (including 2.5G, sub3G)	4G
Major Requirement Driving Architecture	Predominantly voice driven - data was always add on	Converged data and voice over IP
Network Architecture	Wide area cell-based	Hybrid - Integration of Wireless LAN (WiFi, Bluetooth) and wide area
Speeds	384 Kbps to 2 Mbps	20 to 100 Mbps in mobile mode
Frequency Band	Dependent on country or continent (1800-2400 MHz)	Higher frequency bands (2-8 GHz)
Bandwidth	5-20 MHz	100 MHz (or more)
Switching Design Basis	Circuit and Packet	All digital with packetized voice
Access Technologies	W-CDMA, 1xRTT, Edge	OFDM and MC-CDMA (Multi Carrier CDMA)
Forward Error Correction	Convolutional rate 1/2, 1/3	Concatenated coding scheme
Component Design	Optimized antenna design, multi-band adapters	Smarter Antennas, software multiband and wideband radios
IP	A number of air link protocols, including IP 5.0	All IP (IP6.0)

Convergence in NGN

- Convergence of :
  - Fixed and mobile applications
  - Carrier class utilization @ 99.9999% availability
  - Simple transport of data from 2G to 2.5 to 3G
  - High cost reduction and positive RoI within less than 1 year
  - Maximum ARPU

Conclusion and way forward for 4G

- **Lower Price Points Only Slightly Higher than Alternatives** –
- **More Coordination Among Spectrum Regulators Around the World** - Spectrum regulation bodies must get involved in guiding the researchers by indicating which frequency band might be used for 4G.
- **More Academic Research**: Universities must spend more effort in solving fundamental problems in radio communications (especially multiband and wideband radios, intelligent antennas and signal processing.
- **Standardization of wireless** networks in terms of modulation techniques, switching schemes and roaming is an absolute necessity for 4G.

Conclusion and way forward

- **A Voice-independent Business Justification thinking**: Business development and technology executives should not bias their business
- **Integration Across Different Network Topologies**: Network architects must base their architecture on hybrid network concepts.
- **Non-disruptive Implementation**: 4G must allow us to move from 3G to 4G.

References:

1. Development of IMT-2000 systems ; ITU
2. Deployment of IMT-2000 systems; ITU
3. Guidelines for a smooth transition from 2g to IMT 2000; ITU
4. ITU Radio standards; ITU-R