Outline

- Introduction
- Evolution of wireless networking
- Next generation network – convergence of heterogeneous access networks around an IP core
- Service convergence over IP multimedia subsystem (IMS)
- Service Oriented Architecture (SOA) as an enabler for service convergence
- Technical challenges in service and network convergence
- Research at UBC addressing these challenges
- Some recent results and future directions
- Conclusions

The University of British Columbia

- 102 years old
- A world class university with a spectacular location
- Consistently ranked among world’s top 50 universities
  - #30, London Times Higher Education World University Ranking 2010
  - #36, Shanghai Jiaotong University World University Ranking 2010
- Annual budget of $1,600,000,000
- More than 50,000 students
- 12 faculties and 11 schools, 2 campuses in Vancouver and Kelowna
- World class faculties in medicine, life sciences, law, engineering and management
- One home-grown and one resident Nobel Laureates
  - Michael Smith, Nobel Prize in chemistry, 1993
  - Carl Wieman, Nobel Prize in physics, 2011

Dept. ECE @ UBC

- 56 faculty members, 11 IEEE Fellows
- Two graduate degrees: BASc EE, BASc CE
- Three postgraduate degrees: PhD, MASc, MEng
- Approximately 800 undergraduate students (year 2, 3, 4) and 350 graduate students
- Research groups:
  - Biotechnology Group
  - Communications Group
  - Control and Robotics Group
  - Computer and Software Engineering Group
  - Electric Power and Energy Systems Group
  - Microsystems and Nanotechnology Group
  - Signal Processing and Multimedia Group
  - Very Large Scale Integration Group

Communications Group @ ECE, UBC

- Vijay Bhargava – error correcting codes, wireless systems and technologies beyond 3G, cognitive radio
- Lutz Lampe – modulation and coding, MIMO systems, CDMA, ultra-wideband (UWB), wireless sensor networks
- Cyril Leung – wireless communications, error control coding, modulation techniques, multiple access, security
- Victor Leung – network protocols and management techniques, wireless networks and mobile systems, vehicular telematics
- Dave Michelson – propagation and channel modeling for wireless communications system design, low-profile antennas
- Robert Schober – detection, space-time coding, cooperative diversity, CDMA, equalization
- Vincent Wong – wireless networks, ad hoc, sensor networks

strong research focus on wireless
My Research Focus

- Network architectures, protocols, management algorithms, modeling and performance evaluations
- Two main thrusts:
  - Wireless telecom 3G and beyond
    - Radio resource management for high speed packet access
    - Interworking of heterogeneous wireless networks
    - Handoff and mobility management
    - Quality of service provisioning
    - Authentication, authorization and accounting
  - Networking for license-free wireless communications
    - Wireless personal area networks
    - Wireless sensor networks
    - Vehicular ad hoc networks and vehicle-infrastructure integration
    - Wireless body area networks
    - RFID networks

My Team

- Postdoctoral fellows – Dr. Alireza Attar, Dr. Sergio Gonzalez, Dr. Hongbo Guo, Dr. Sang-Wook Hau, Dr. Xuedong Liang
- PhD students – Naim Arianpoo, Amr Al Asaad, Mohsen Amiri, Asifulla Comite, Javad Hajipour, Peyman Talebifard, Narsey Touabi, Jie Wang, Jie Zhang
- MASc students – Wei Bao, Xiaolei Hao, Geoffrey Lu, Madhu Sharma
- Collaborators – Prof. Henry Chan (Polytechnic U. of HK), Prof. Min Chen (SNU Korea), Prof. Jianmeng Cao (Polytechnic U. of HK), Prof. Sabitha Gopalakrishnan, Dr. Song Guo (Aizu U. Japan), Prof. Hong Li (BUPT, China), Dr. Zhifeng Jiang (China Netcom), Prof. Yikuan Jinduangthirath, Dr. Ke-Dong Lee (LG), Prof. Panos Nasiopoulos, Dr. Qixiang Pang (General Dynamics), Dr. Helen Tang (DRDC), Prof. Son Vuong (UBC CS), Mr. Terrence Wong (Huawei Canada), Prof. Vincent Wong, Prof. Oliver Yang (U. Manitoba), Prof. Jie Yu (Carleton U.), Dr. Yan Zhang (Simula), Prof. Qian Zhang (HKUST), Prof. Yihua Zhu (Zhejiang U. Technology)

Historical Perspectives of Wireless Communications

Dawn of Wireless Communications

- Wireless communications began in 1895 when inventors including Guglielmo Marconi, Alexander Popov and Nicola Tesla independently demonstrated radio transmission/reception
- Marconi patented wireless telegraph in England in 1896
- First voice transmission over radio made by Fessenden, a Canadian, in 1900
- Dec. 1901 Marconi made historic trans-Atlantic transmission from St. John, Newfoundland, Canada to Cornwall, UK.

Marconi’s Radio

(circa 1895)

Transmitter

Receiver

Growth of Wireless Communications

- Two-way FM mobile police radio first used in 1940
- First communications satellite launched in 1957
- ALOHANET launched at University of Hawaii in 1971
- AMPS tested in 1978 and deployed in 1984
- GSM launched in 1994
- IEEE 802.11 first released in 1997
Maturing of Wireless Communications

- Digital cellular wireless wide area network (WWAN)
  - 2.5G (GPRS, EDGE, CDMA 1xRTT) made wide area wireless data services widely available
  - 3G (UMTS and cdma2000) now widely deployed
  - 3G+ (3GPP LTE) standardized, LTE-Advanced under development
- Wireless local area network (WLAN)
  - IEEE 802.11 WLAN specification first released in 1997, followed by 802.11a/b in 1999 and 802.11g in 2003, 802.11i in 2004
  - WiFi Alliance formed in 1999 to promote interoperability
- Wireless personal area network (WPAN)
  - Bluetooth standardized by SIG in 2001
  - IEEE 802.15.1 WPAN specification published in 2002
  - IEEE 802.15.4 low-rate WPAN published in 2006
- Wireless metropolitan area network (WMAN)
  - IEEE 802.16d and 802.16e released in 2004 and 2005
  - WiMAX Forum formed to promote interoperability
- Increased pace of new developments of WWAN, WMAN, WLAN and WPAN

World of Wireless Networking

Service and Access Convergence over IP Networks

Current State: Multiple Networks for Multiple Services
Next Generation: Heterogeneous Networks Converged over IP Core

NGN Requirements
- Multi-service, multi-protocol, multi-access, IP based network
  - Multi-services: delivered by a common QoS enabled core network
  - Multi-access: many access networks; fixed and mobile terminals
  - Strong emphasis on security over a managed IP network
- Enabler for service providers
  - Communication services supporting real-time and non-real-time applications between peers or in a client-server configuration
- Roaming and mobility
  - Both users and devices
  - Intra- and inter-network domains
  - Between fixed and mobile networks
- Interoperability with legacy and new services and networks
- Regulatory compliance
  - Legal intercept, number portability, emergency calls, etc.

Next Generation Network Architecture

IP Multimedia Subsystem (IMS)
- Developed by 3GPP (release 5) and adopted by 3GPP2, TISPAN, OMA, …
- Support interworking of heterogeneous access networks, e.g., UMTS, cdma2000, WLAN, WMAN, DSL, …, with Internet and legacy circuit-switched network
- Support subscriber roaming and mobility
- Support interactions between subscriber’s home network, visited network, and third party providers of multimedia services and applications
- Common platform for rapid creation of multimedia services / applications and new revenue generation opportunities

Service Delivery over IMS
- Enables policy based service delivery
- Employs Session Initiation Protocol (SIP) to set up multimedia sessions with roaming support
  - Audio, video, image
  - Communications, streaming, broadcasting
- Support of quality of service (QoS) negotiation and provisioning
- Consolidated billing for sustainable business model

IMS Architecture

CSCF – Call Session Control Function
HSS – Home Subscriber Server
AS – Application Server
MGCF – Media Gateway Control Function
BGCF – Breakout Gateway Control Function
MMFC – Media Resource Function Controller
AN – Access Network
PSTN – Public Switched Telephone Network
Business Aspects

- Transitioning of enterprises from centralized data architecture towards content aware networking
  - Service providers will become strategic suppliers of services rather than providers of bandwidth commodity
- Existing IP infrastructure can be deployed for content aware networking with the following advantages:
  - Shared infrastructure to enable Service Oriented Architecture (SOA) or distributed applications
  - Less performance degradation and lower data latency
  - Less complexity on application servers

Converged Network Architecture

- Service Oriented Architecture (SOA): A key design principle for NGN
- Service layer
  - Service delivery platform (SDP)
  - Centralized policy management and enforcement
  - Service enablers
- Session control layer
- Interworking and access layer

Service Layer in SOA

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Service Delivery Platform Functions

- Interface with external applications via Parlay X module, which provides a set of easy-to-use web service APIs
- Interconnect internal applications and service enablers that use various APIs
- Monitor and collect charging information for all applications
- Control access to network resources via the policy enforcement functions

Policy Enforcement

- End user subscription / class
- Service Level Agreements
- End user account status
- Access network
- End user equipment
- End user preferences
- Network resource availability

Billing and Charging

- Real-time support of online (prepaid) and offline (postpaid) billing systems
- Capturing volume, duration, application, transaction, etc.
- Consolidation of all communications onto a single standardized interface with the charging agents
Billing / Charging Architecture

QoS Provisioning

Enabled Services

- Conversational communications
  - Voice convergence
  - Video calls
  - Push-to-X call
- Location Based Services
  - Emergency broadcast
- Message based communications
  - Multimedia messaging services
  - Instant messaging
  - Content on demand communications
- And more…

Technical Challenges of Convergence

- Selection of access network for service invocation
  - Providing “Always Best Connected” (ABC) service
- Personalization and adaptation of subscriber services
  - User identity and profile management
  - Location management
  - Mobility management
  - Management of subscribers and services over heterogeneous access networks
  - Vertical handoff decision and execution
  - Adaptation of multimedia streams
- End-to-end QoS provisioning, network resource management
- Authentication, authorization and accounting (AAA) for subscriber service access across heterogeneous access networks

Ongoing Research at UBC

- Most of the work funded by TELUS, Bell Canada, NSERC under projects:
  - Provisioning and management of IP-based multimedia mobility services over heterogeneous broadband wireless networks
  - Towards the next generation telecommunication networks – Service integration over multi-technology access networks
  - Interworking between cooperative access networks over IP backbone
- Development of a policy-based access management framework
- Cross-layer adaptation of multimedia streams
- Fast authentication protocol over heterogeneous wireless access networks
- Selection of access network for service invocation
- Optimization of vertical handoff decisions and seamless handoff operations

Network Selection for Service Delivery across Heterogeneous Wireless Networks

Farooq Bari and Victor Leung
Significance of Network Selection

- Reliable network selection mechanisms are essential for working of NGNs supporting heterogeneous wireless technologies
- Necessary action before service invocation when devices equipped with multiple radio interfaces
- Network selection impacts customer satisfaction and service experience
- An appropriately selected network can decrease possible inter technology handoffs later on
- Network selection issues are currently under discussion in major industry / standards forums such as IEEE 802, IETF, 3GPP, 3GPP2

Architectural Options

- **Network based approach** – may not be feasible in heterogeneous networking environments
- **Terminal based approach** - the terminal itself discovers available networks, collects data from candidate networks, analyzes the data and makes the selection
- **Network assisted approach** - the terminal uses the network to assist in the selection process by relying on the network to find roaming partners, collect data from candidate networks and analyze the data to come up with recommendations; user or terminal makes decision on the selection based on the recommendations

Proposed Architecture – Network Assisted Approach

- **User equipment**
- **Wireless Access Networks (AN)**
- **Partner Networks (PN)**
- **Home Network (HN)**

Proposed Architecture

The following functions are added to each network domain:

- **Network Information Node (NIN)**
  - Information collector function (ICF) – Monitors and collects information on network conditions
  - Information provider function (IPF) – Stores and exchanges this information across autonomous domains

- **Service Information Node (SIN)**
  - Announces the services available to users via different networks at users’ current location

- **AAA Node**
  - Deals with multimedia terminals that have to exchange information such as user identity, HN identity with backend servers while working across different network types.

Policy Based Network Selection

<table>
<thead>
<tr>
<th>QoS Requirements</th>
<th>Application Function e.g. Call Session Control Function (CSCF)</th>
</tr>
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<tbody>
<tr>
<td>Policy Decision Function</td>
<td>Service Information Network Information Authentication, Authorization and Accounting (AAA)</td>
</tr>
<tr>
<td>Policy Enforcement Function</td>
<td>Transport Layer Components</td>
</tr>
</tbody>
</table>
Attributes Impacting Network Selection

1. AAA Mechanism
2. Access Technology
3. Services Available
4. Geographic Location
5. Coverage Area
6. Cost per Byte
7. Total Bandwidth
8. Allowed Bandwidth
9. Utilization
10. Packet delay
11. Packet Jitter
12. Packet Loss

Multi Attribute Decision Making (MADM)

- Making preference decisions over the available alternatives while taking into consideration multiple criteria impacting the decision
- Provide solution in discrete decision spaces where decision alternatives are predetermined
- Attribute values can be deterministic, fuzzy or stochastic
- MADM involves the following steps:
  1. Identify all alternatives and attributes impacting the decision process.
  2. Assign relative importance in the decision making process to each of the attributes
  3. Use a MADM algorithm to get a ranking / preference for the alternatives
- Many MADM algorithms exist, such as TOPSIS, ELECTRE, GRA
  - Need improvements and adaptations to apply towards network selection problem

Optimization of 3G/WLAN Vertical Handoff Decisions

Jie Zhang, Henry Chan and Victor Leung

Handoff Management in NGN

- Conventional (intra-system) handoff:
  - Horizontal handoff
  - Compulsory to maintain connection
  - Not direction dependent
- Mobile devices in NGN will be equipped with multiple radio interfaces
- Inter-system or inter-technology handoffs:
  - Vertical handoff
  - Directional dependent
  - Downward handoff, e.g., cellular → WLAN
    - optional to maximize the satisfaction on service
    - to handoff or not to handoff …
  - Upward handoff, e.g., WLAN → cellular
    - compulsory, to keep the call connectivity

Downward Handoff Decision

- Goal: provide ABC service, maximize overall user satisfaction utility
- Handoff gain
  - Service enhanced by accessing broadband wireless network (BWN), e.g., WLAN
  - Proportional to connection period
- Handoff cost
  - Service degradation during vertical handoff, such as packet lost, signalling cost
  - One-time costs:
    - cost for downward handoff
    - cost for upward handoff when MT moves out of BWN coverage before session ends
- Handoff only if the gain offsets the cost
- Decision depends on
  - Mobility: the sojourn period of MT in BWN
  - Traffic: connection lifetime

Optimization of Handoff Decision

- Utilize discounted Markov Decision Process to optimize downward handoff decisions at regular time intervals
- Assume mobiles equipped with location tracking capability and report positions and RSS of BWNs to a location service server (LSS), which determines possibly irregular coverage boundaries of BWNs at the vicinity of a mobile
- Mobile’s movement modeled by a Gauss-Markov mobility model differentiated according to mobile’s situation, e.g., open area or roadway
- Mobile’s connection length assumed exponentially distributed
- Expected sojourn time in BWN estimated when entering BWN coverage area based on mobility and traffic model
- Execute downward handoff if expected utility for the connection is increased by the handoff
Comparison of Utility Enhancements

Harmful Handoff Probability

Handoff Probability

Possible Future Research Directions

• Context-aware services
  – Context management: identity, role, location, situation, activity, time
  – Information from smart phones and other sensors
  – Service enabler providing context information to applications
• Integration with global IT infrastructure to enable eSociety
  – Leveraging cloud computing
  – Interworking with smart power grids
  – Interworking with intelligent transportation systems
  – Integration with eHeath system

Conclusions

• Next generation network supports access network and service convergence based on a common IP core network
• IMS provides signaling support for service access, connection establishment, roaming, handoff support, QoS provisioning, …
• SOA built on top of IMS provides basis for converged services over next generation network
  – Policy management
    – Common billing
    – QoS support
• Significant research challenges exist in providing ABC services over the next generation networks
• Recent results on network selection and vertical handoff optimization
• Possible future research directions discussed

Thank you!