Course Introduction

EE392I: Seminar on Trends in Computing and Communications

http://www.stanford.edu/class/ee392i/

Spring 2018

Jatinder Singh
General Seminar Introduction

- 5+ year trends
  - lasting influence on computing & communications landscape
  - covering platforms, infrastructure, algorithms, enterprise services, and consumer applications
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- **5+ year trends**
  - lasting influence on computing & communications landscape
  - covering platforms, infrastructure, algorithms, enterprise services, and consumer applications

- **Invited talks**
  - Industry/academia/venture capital sectors

- **This quarter:**
  - Mobile networks, cloud data management, search and machine learning, IoT and edge computing
This year’s seminar Motivation

- Research, innovation and hi-tech industry landscape over the past decade
  - services and software sector has flourished in past decade
  - infrastructure and h/w being increasingly commoditized
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- Past 5-8 years
  - Data consumption growth across the board: consumer and enterprise.
  - Mobile platforms becoming pervasive
  - Migration of enterprise and IT infrastructures to cloud computing paradigms.
  - Increased in complexity for the enterprise, over-loaded mobile networks, security concerns associated with device mobility.
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- Seminar significance
  - First hand exposure to these trends
  - Opportunities for businesses, research and development

- This year’s class composition ...
Class Logistics

- 1 unit class
- Grading: Credit/No Credit based on class attendance and submissions
- Submissions
  - Class Summaries (at least 8/9)
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- Submissions
  - Class Summaries (at least 8/9)
- Class Attendance
  - Sign in sheet will be circulated at the beginning of every class
  - Attend at least 8 classes
- Office Hours: Thursdays, after class, here.
- Instructor: Jatinder Singh (jatinder@stanford.edu)
Class Submissions (Lab/Section component)

- Class Summaries
  - Concise summary of the lecture/talk: your thoughtful evaluation of one or more aspects that you learnt and (optionally) how these could lead you to pursue a research problem or advance state-of-the-art via R&D or a start-up. The summary of the whole class not necessary.
  - Submit at least 8, online.
  - Due within one week of each class.
This quarter’s Agenda

- Cellular Networks: Paradigms, Architecture, and Mobility
- **Guido Appenzeller, CTO, Cloud & Networking, VMware:** Migration of Enterprise IT to the cloud
- **Satyajeet Salgar, Product Manager, Google:** Google Search and Machine Learning
- **Jeremy Clark, Executive Director of Strategy & Operations, Comcast:** Innovation principles under limited time and information
- **Shubha Nabar, Director of Data Science, Salesforce:** Building products using machine learning
- **Soham Majumdar, Co-founder, Rubrik, Cloud Data Management:** orchestrating data for hybrid cloud enterprises anytime, anywhere
- **Tamara StClaire, COO, Basehealth, Inc:** Innovation in Healthcare
- **David Arthur, Google:** Google Search Ads Infrastructure
- **Satyam Vaghani, Vice President:** Nutanix
Lectures 1 - Cellular Networks: Paradigms, Architecture, and Mobility

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Agenda

- Basics & Technology Evolution
  - GSM Legacy Architecture and Functionality
  - Cellular Mobility
  - Alternative Models and Transformed Architectures
    - Alternative wide-area wireless access technologies
    - Convergence
    - All IP paradigms
- Comparison with Internet and sample scenario studies
- Economics of operation
- From a clean slate
Cellular Networks Basics: Structure

- Mobile Station: Distributed transceivers
- Base Station: Fixed transceiver
- Downlink
- Uplink
- Handoff
- Multiple Access
- Cells
  - Different Frequencies or Codes
Basics: Multiple Access Methods

- **TDMA**: Time Division Multiple Access
- **FDMA**: Frequency Division Multiple Access
- **CMDA**: Code Division Multiple Access
Some More Basics

- Uplink & Downlink separated in
  - Time: Time Division Duplex (TDD), or
  - Frequency: Frequency Division Duplex (FDD)

- Information (voice, data) is digitized and bit streams modulated onto carrier

- Modulation, data redundancy (coding), transmission power, data retransmissions (ARQ) adapted to varying wireless channel quality

- Spatial attenuation of signal
  - Frequency or codes can be reused (frequency reuse)
Cellular Technology Evolution

- Early mobile radio systems (e.g. MTS)
- 1G: Analog
- 2G/3G/4G/5G .. - digital:

| 2G (+) | 3GPP     | 3GPP2       |
|        | GSM      | cdmaOne/IS-95 |
|        | GPRS     |              |
|        | EDGE     |              |

| 3/4/5G  | UMTS, WCDMA | CDMA2000 |
|         | HSPA         |         |
|         | LTE          | EV-DO   |
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2G: 900/1800 MHz bands (US: 850/1900 MHz)

For 900 MHz band

- Uplink: 890-915
- Downlink: 935-960

25 MHz bandwidth - 124 carrier frequency channels, spaced 200KHz apart

Time Division Multiplexing for 8 full rate speech channels per frequency

Handset transmission power limited to 2 W in GSM850/900 and 1 W in GSM1800/1900.
Legacy Architecture

Structure of a GSM network (key elements)

- Base Station Subsystem (BSS)
  - BTS
  - BTS
  - A-bis
  - Air (Um)

- GPRS Core Network
  - SGSN
  - GGSN
  - Gb
  - Gn
  - Gr / Gs
  - Gi

- Network SubSystem (NSS)
  - MSC / VLR
  - PSTN
  - SS7 Network
  - H/E etc
  - HLR AUC (EIR)
  - The Internet (or a corporate)

Interface Names
# Cellular Networks and Internet

<table>
<thead>
<tr>
<th></th>
<th>Cellular Networks</th>
<th>Internet</th>
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</thead>
<tbody>
<tr>
<td><strong>Incipient Service</strong></td>
<td>Voice</td>
<td>Data</td>
</tr>
<tr>
<td><strong>Technology</strong></td>
<td>Circuit Switched Analog</td>
<td>Packet Switched</td>
</tr>
<tr>
<td></td>
<td>Circuit Switched Digital</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C.S. Voice + P.S. Data</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P.S. Voice, Data</td>
<td></td>
</tr>
<tr>
<td><strong>Evolution</strong></td>
<td>Controlled</td>
<td>Semi-Organic</td>
</tr>
<tr>
<td><strong>New Services</strong></td>
<td>Operator initiated</td>
<td>Third party/</td>
</tr>
<tr>
<td></td>
<td></td>
<td>independent (largely)</td>
</tr>
<tr>
<td></td>
<td>Third party/partnered</td>
<td></td>
</tr>
<tr>
<td><strong>Mobility Support</strong></td>
<td>Good</td>
<td>Poor</td>
</tr>
</tbody>
</table>
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Mobility

- An inherent and crucial feature of wireless networks
- User mobility warrants re-association with network point of attachment
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- Handoff frequency depends on
  - coverage area of BS/AP, and
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- Handoff frequency depends on
  - coverage area of BS/AP, and
  - user bearing
- Continuity of applications including voice/data connections -> minimal disruption during the transition.
  - Constraints on permissible hand-off delays
Handoff in Cellular Networks

- Changing association of mobile station from one BS to another
  - Necessary to support mobility
  - Network/Mobile initiated
  - Hard/Soft

- Target cells: neighbor list

- Hand-off Decision Criteria
  - Signal strength/BER/speech quality/..

- Inter-System / Vertical Handoffs
  - Cellular/WiFi/WiMAX/..
Roaming in GSM based networks

- Roaming subscriber registers/notifies serving MSC of location
- Registration transferred to home MSC -> HLR updated
- Visitor MSC updates VLR by requesting info for roaming node over SS7
- Calls to roaming subscriber routed accordingly by the network
Mobile node gets long term IP address (home address) from HA
- When roaming - > Care of Address (CoA)
- Home Agent tunnels datagrams to mobile node
- FA detunnels and delivers datagrams to mobile node and can act as default router for outgoing traffic
- Mobile node able to communicate with entities having no MIP functionality.
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Alternative fixed wireless and MAN standards

- WiMAX, the Worldwide Interoperability for Microwave Access based on IEEE 802.16 standard
- Applicable scenarios include last-mile broadband access, backhaul for cellular networks, Internet Services
- 802.16 - Fixed WiMAX, 802.16e/m - Mobile WiMAX.
- Licensed spectrum profiles: 2.3GHz, 2.5GHz and 3.5GHz. US mostly around 2.5 GHz.
Wireless Mesh Networks

- Wireless nodes deployed in a mesh topology provide coverage to clients.
- Relay nodes pass on data and are connected to the Internet via gateways.
- Relatively inexpensive means for deploying wireless access.
- Multi-radio mesh networks (e.g. IEEE 802.11 g/a).
- Municipal WiFi Networks prevalent to provide city-wide connectivity.
Convergence

- Heterogeneous access technologies
  - Multi-homed phones (WiFi, xG)
- Heterogeneous Services
- Cellular Internet access and Internet based voice/video access
- Challenges to efficient resource utilization
  - Time variant heterogeneous network characteristics
  - Heterogeneous applications with different utilities
  - System design and networking challenges
- Several past and ongoing research initiatives
  - References on class website
Next generation / All IP networks

- Proliferation - mobile access to Internet services
- Packet-switched architectures integrating IP and wireless technologies - consolidation of multiple transport networks to all-IP core.
- Network provisions heterogeneous services (voice, data, multimedia..) via packetized transport.
- Less operational expense and easy deployment of new services by providers.
- ITU-T definition:

A Next generation network (NGN) is a packet-based network which can provide services including Telecommunication Services and able to make use of multiple broadband, QoS-enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies. It offers unrestricted access by users to different service providers. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users.
NGMN Historically Envisioned Architecture

Source: http://www.ngmn.org
Evolution to Simplified Architectures – An Example

- Evolved Packet Core in LTE
- EPC adopts a flat architecture as compared to HSPA
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Internet: Sample scenario – Residential Broadband access

Technology Fragmentation hinders flexibility / innovation:

- QoS: Wireless hop (802.11e?), PPPoE, IP QoS (Diffserv) and translation mechanisms
- Mobility Options: MIP - high-barrier, delay performance, incremental patch rather than clean solution?
Classical Cellular Scenario

Better QoS, scheduling
Better Mobility support within network
Integrated voice/data Authentication
Downside is excessive edge network delays, costs of network deployment.
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The Economics

- Spectrum licensing and migration cost
  - Economics of operation: meeting bids vs. system upgrades for technical innovation
- Stiff competition for both fixed and mobile segments of operators
- Explosion in data traffic, revenue per bit decline
- Drive towards services, but deploy-ability barriers?
- Interesting and sometimes conflicting dynamics for operators with fixed and mobile operation
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From a Clean Slate

- Greater intelligence at edges of networks, eventually leading to just network elements of different sizes and capabilities (distributed intelligence)
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- Functional homogeneity in network elements in terms of storage/caching, processing, networking capability. Such network element should likely
  - be multi-homed connected with heterogeneous technologies (including p2p, delay tolerant),
  - have intelligence for resource allocation, QoS
  - have interaction capability with other network elements (including user devices),
  - support mobility, handoffs
  - have ability to recognize needs of existing and new applications (HDTV, phone, streaming video)
  - be plug and play
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- Interfacing of applications/services (QoS specs) with underlying serving networks for fast and easy deployment.
- Heterogeneity in access technologies amongst user carried devices honored and accepted by the network elements.
Options for operators

- Sharing spectrum/infrastructure costs, or regulatory mandates instead
- New application partnership models
- Good opportunity for fixed and mobile carriers to reduce operational cost
- Making use of research and open innovation paradigms
- ...
