Video Streaming over Mobile Networks: Issues, Challenges, and Opportunities

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Audio/Video recordings of this talk are available at:

http://www.cse.wustl.edu/~jain/talks/wcmn11.htm

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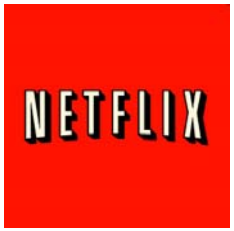
1. Video Streaming: Challenges
2. Research Opportunities
3. Our Research Projects
4. Efficient solutions to WCMN in Saudi Arabia

What is Streaming?

- Streaming: Showing video without receiving full file first
- Two Types of Streaming Videos:
  - Pre-stored Video: Movies, TV
    ⇒ VCR-like Interactive control

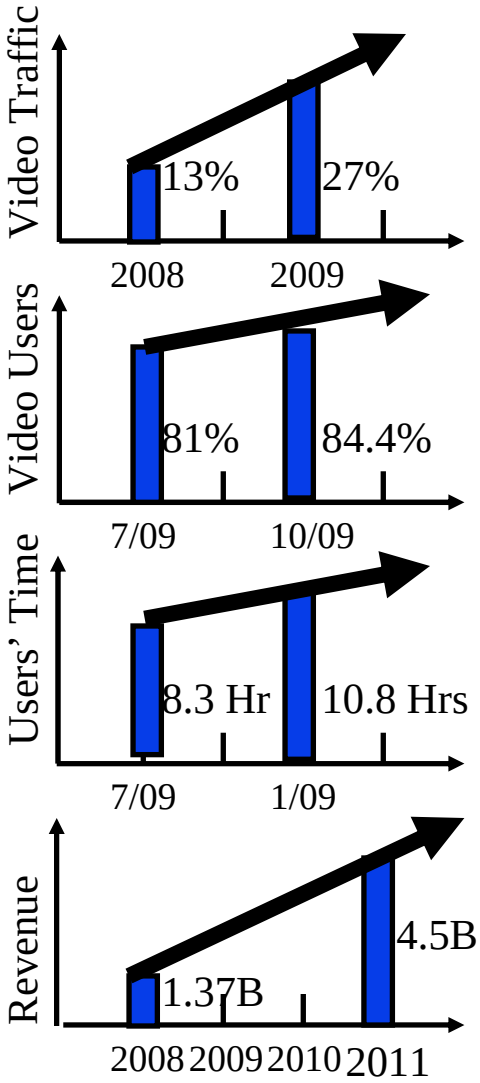


  - Real-time video: Video conferencing, gaming
- Two types of Streaming Communication:
  - One-to-One: Feedback control
  - One-to-Many: Usually no feedback

Ref: Ref: http://en.wikipedia.org/wiki/Streaming_media

Growth in Video Streaming

- In 2008 13% of Internet traffic was video streaming. In 2009, 27% was video streaming [newteevee]
- In July 2009 81% of U.S. Internet users watched streaming videos. In Oct 2009, this number increased to 84.4% [ComScore]
- In July 2009, U.S. Internet users spent on average 8.3 hours/month watching streaming video. This increased to 10.8 hours/months by Oct. 2009 [websitegear]
- Streaming video advertisement revenue is expected to rise from 1.37 billion dollars in 2008 to 4.5 billions in 2011 [masternewmedia]



Why Stream?

- Education: study from home
- World is flat ⇒ Remote work and remote education (Live in Saudi Arabia and work in USA and vice versa)
- Remote video monitoring: E.g., oil and gas industry
- News and Entertainment: Netflix, YouTube, Vimeo, Metacafe, Hulu, Veoh

Streaming Media Requirements

Quality of Experience (QoE) Requirements

- Fast Start: Can delay showing the first frame
  - 10s for non-interactive
  - 2s for channel change
- Quick Response to User (VCR like) commands:
  - Max 200 ms for interactive video/user
- Continuity
  - Delay jitter <16 ms

Ref: DSL Forum, "Triple Play Services Quality of Experience (QoE) requirements," Tech Report TR-126, Dec 2006.

Streaming Media Challenges

- Internet is designed for data
  - All bits are equally important
  - End of transmission is most important ⇒ High throughput
  - Loss is not acceptable

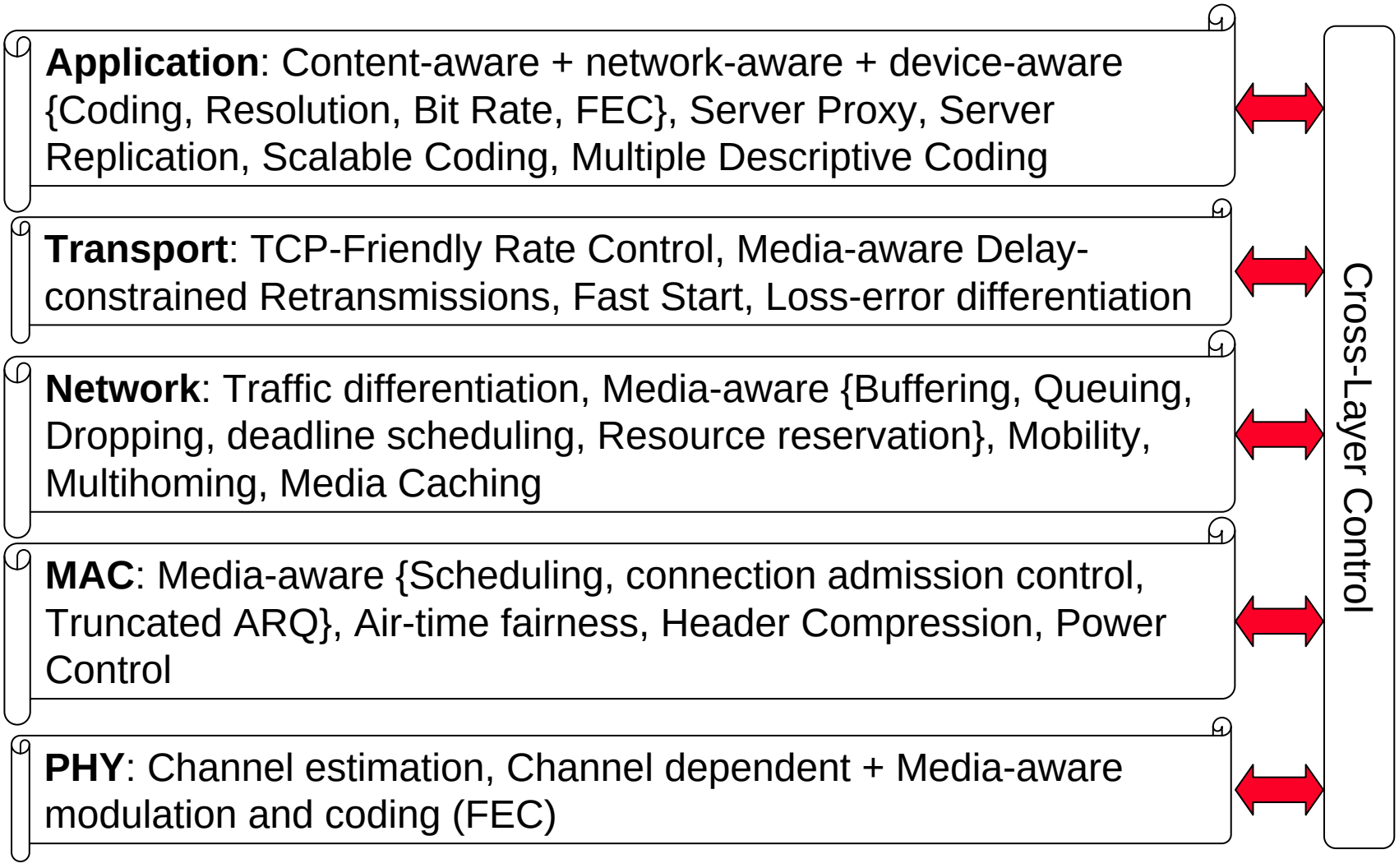
- Streaming Video:
  - Media Differentiation:
    - User control more important than media
    - Voice is more important than video
    - Certain objects in video are more important than others

  - Continuity is important in presence of network
    Late arrivals hurt but early arrivals do not help.
    Starting fast is good but after that throughput does not help.
  - Significant redundancy ⇒ Some loss tolerable

Wireless Challenges

- Internet Protocols are designed for wired network
  - Low loss Rate, Negligible error rate, fixed link capacity
- Wireless introduces new challenges:
  - Low Bandwidth ⇒ High loss rate
  - Interference ⇒ High error rate
  - Bandwidth fluctuation with time ⇒ Dynamic Adaptation
  - Location dependent Bandwidth ⇒ Air-time fairness
  - Limited Battery Life ⇒ Bursty transmission
  - Mobility ⇒ Smooth Handoff
  - User Heterogeneity ⇒ Smart phones, iPads/Laptops, TVs = 2" to 42" screens ⇒ Customization

Research Opportunities

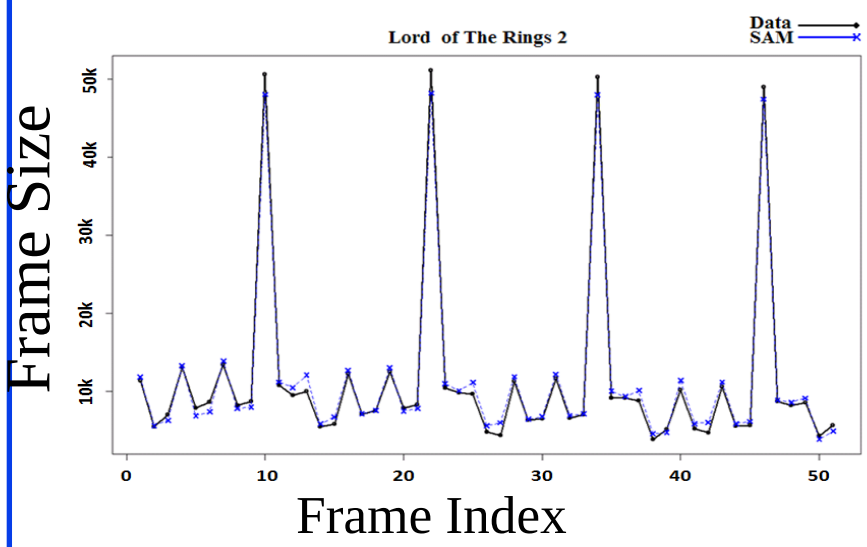


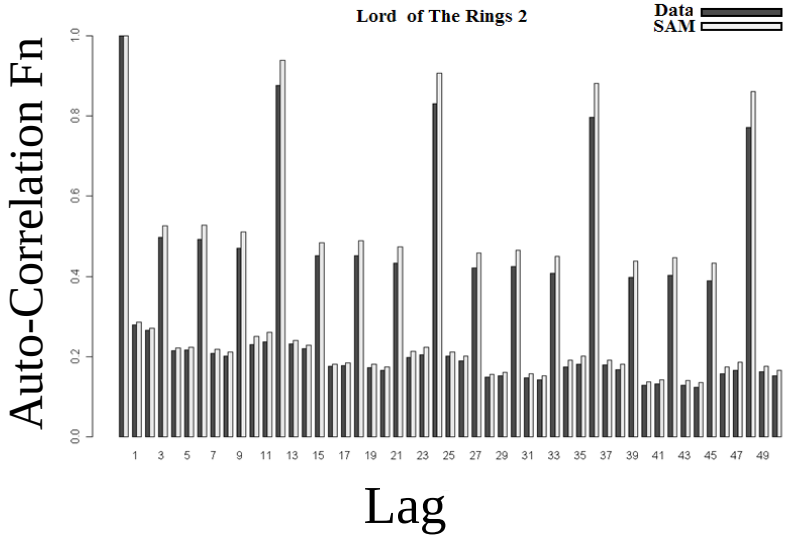
Our Research Projects

1. Traffic modeling and prediction for video scheduling
2. Scheduling for video streaming
3. Wireless loss and error differentiation
4. User mobility
5. Data multihoming

1. Simple Seasonal ARIMA (SAM) Model

- SAM is a time-series model that can predict future video frame size from recent past [Abdel-Karim Al-Tamimi's Thesis]
- One set of parameters for all movies of a particular category
- Applies to MPEG4-Part 2, MPEG4-Part 10/AVC and SVC-TS
- Allows resource scheduling, and traffic generation for testing
- 50 Videos data available http://www.cse.wustl.edu/~jain/sam/



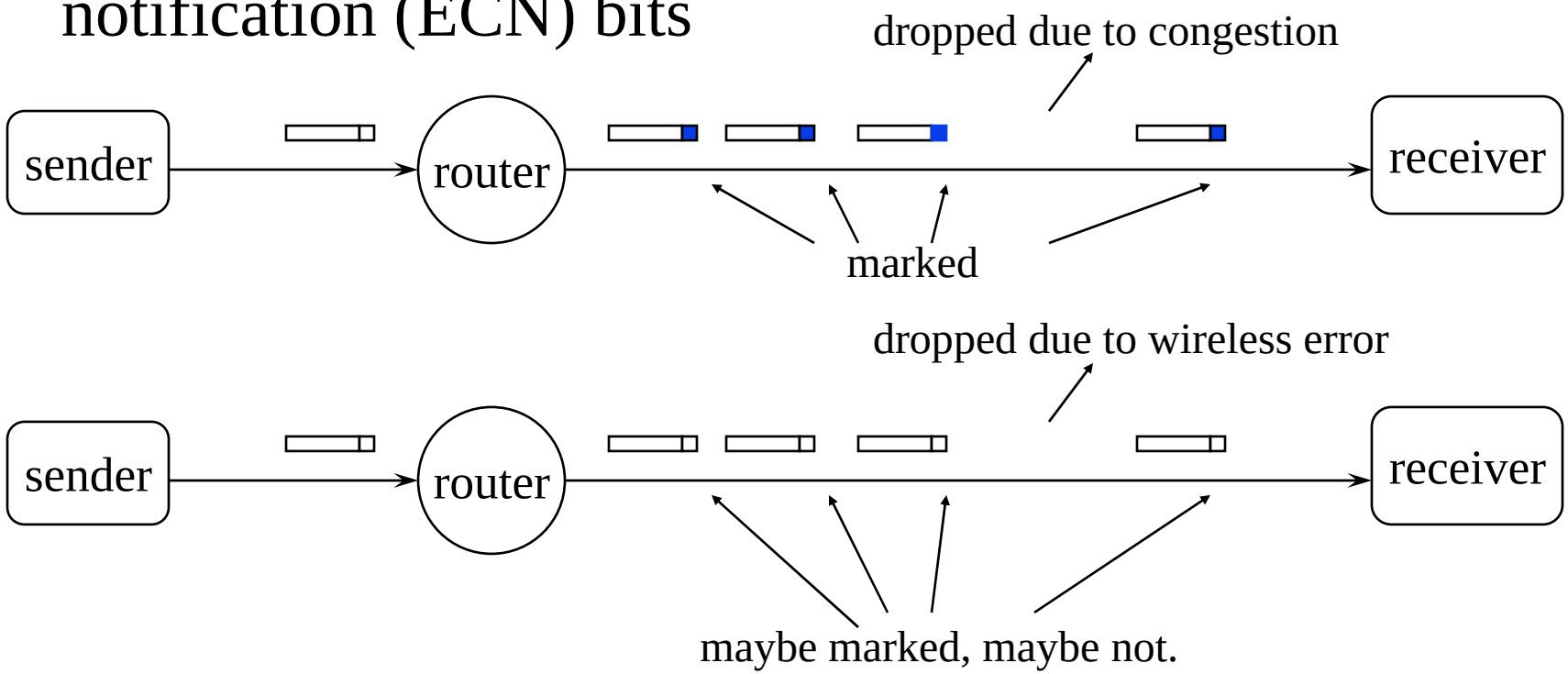


2. Scheduling Streaming Video over WiMAX

- Used SAM as the traffic generator for Real-Time Polling Service (rtPS) class in WiMAX
- Compared 3 different schedulers:
  - Earliest deadline first (EDF)
  - A variation of round robin (RR)
  - A combination = EDF regulated with RR
- Results:
  - In under load, all three meet the throughput and delay constraints.
  - In overload scenario, EDF is unfair. RR and EDF+RR are fair. RR has the highest fairness.

3. Congestion Coherence

- General problem of TCP over wireless: How to distinguish congestion losses from error losses
- Our proposal: Look at the explicit congestion notification (ECN) bits

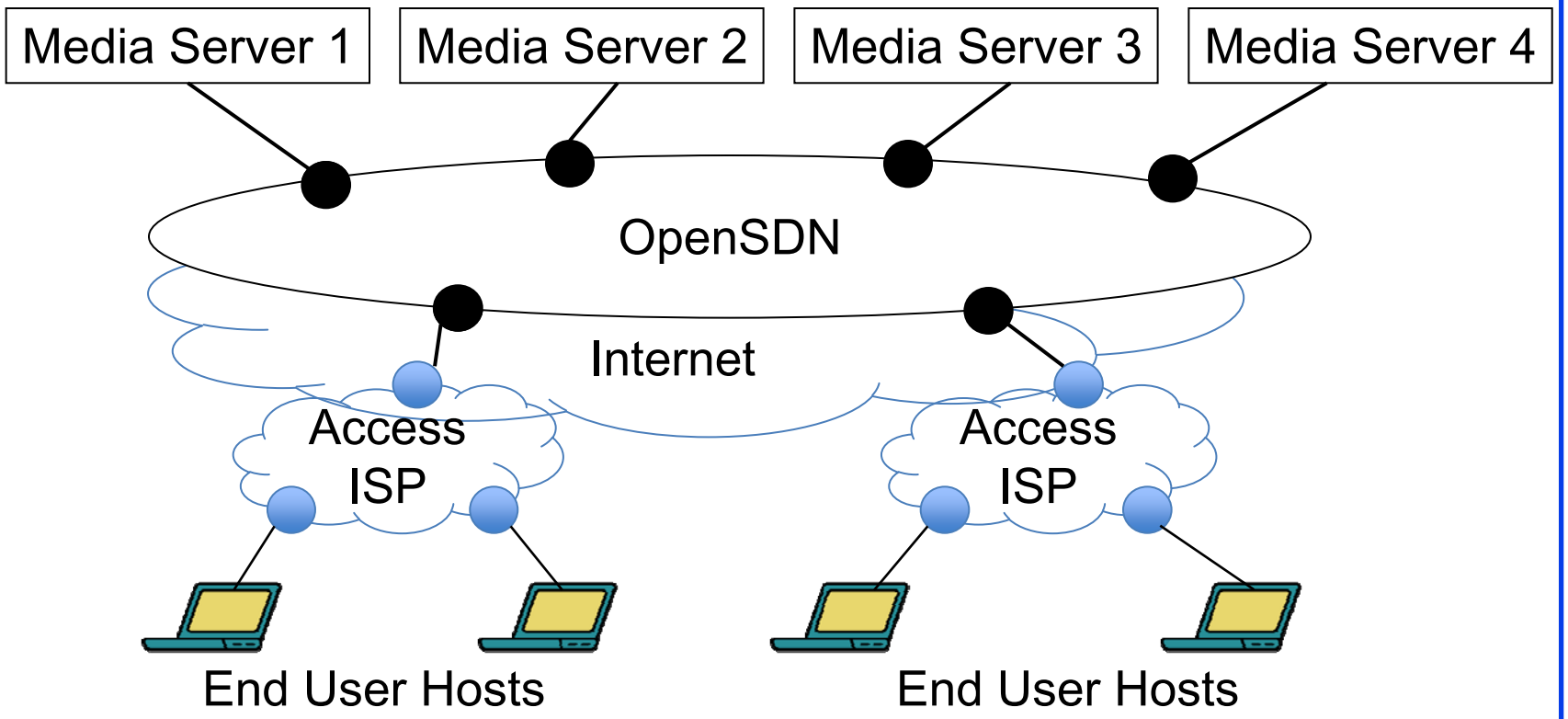


4. User Mobility

- Internet is host-centric: All communication is between two hosts. All mobility discussion is about host mobility.
- Users now have multiple devices. Can't move among devices.
- User Centric View:
  - Bob wants to watch a movie
  - Starts it on his media server
  - Continues on his iPhone during commute to work
  - Since movie exists on many servers, Bob may get it from different servers at different times or multiple servers at the same time
- User/Data Centric views require assigning network names and addresses to user and data objects (in addition to host objects)

5. Open Service Delivery Network (OpenSDN)

- Internet Architecture evolution to support distributed services
- Allows replication, fault tolerance, load balancing
- Streaming media, content distributions are examples of services

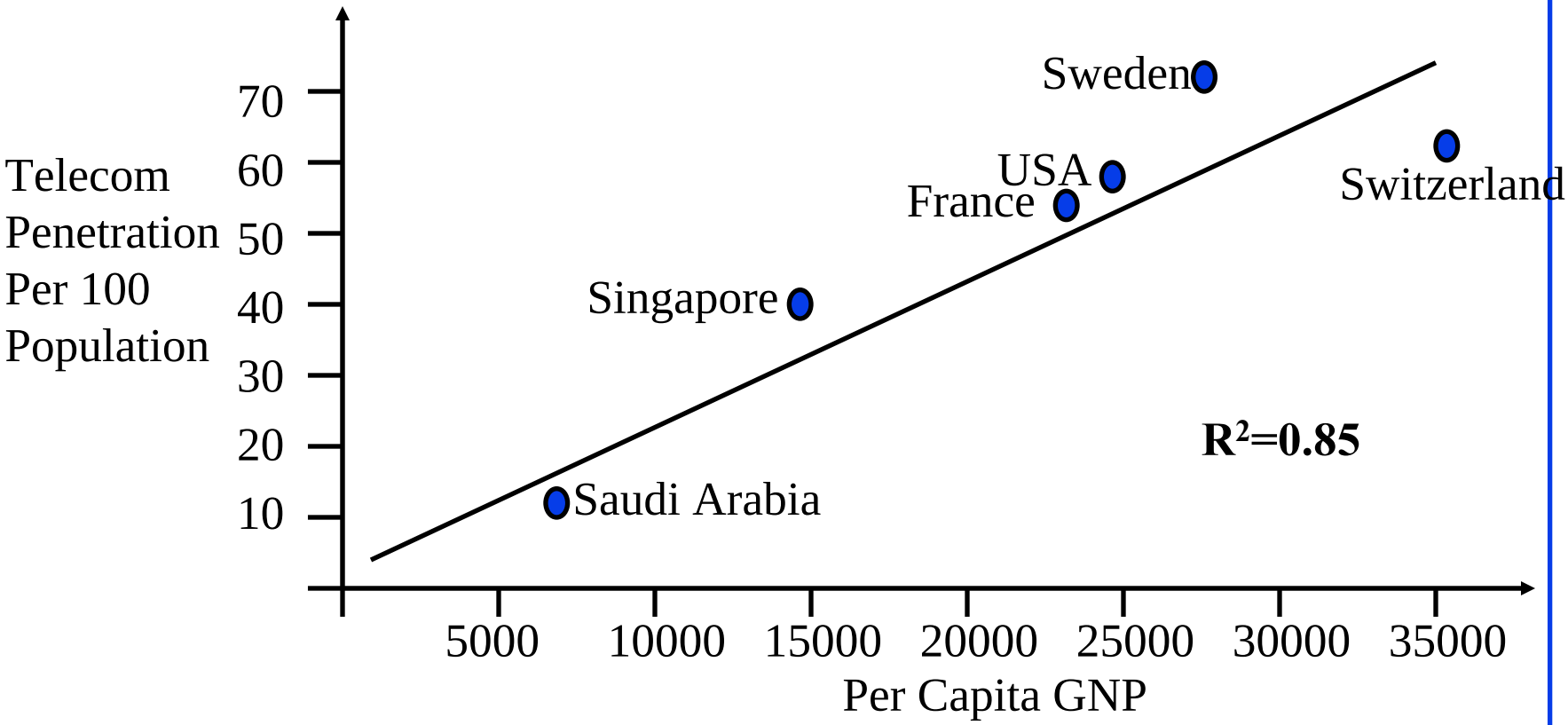


Ref: http://www1.cse.wustl.edu/~jain/talks/comsnets11.htm

Saudi Arabia: Challenges

- Extreme hot weather condition
- Insufficient landline infrastructure
- Need to support Oil and Gas industries
- Growing population of Mobile Internet users with high bandwidth demand

Telecom and Economic Development



- Fundamental correlation between GDP growth and teledensity
- Although this data is old but the conclusion still holds.

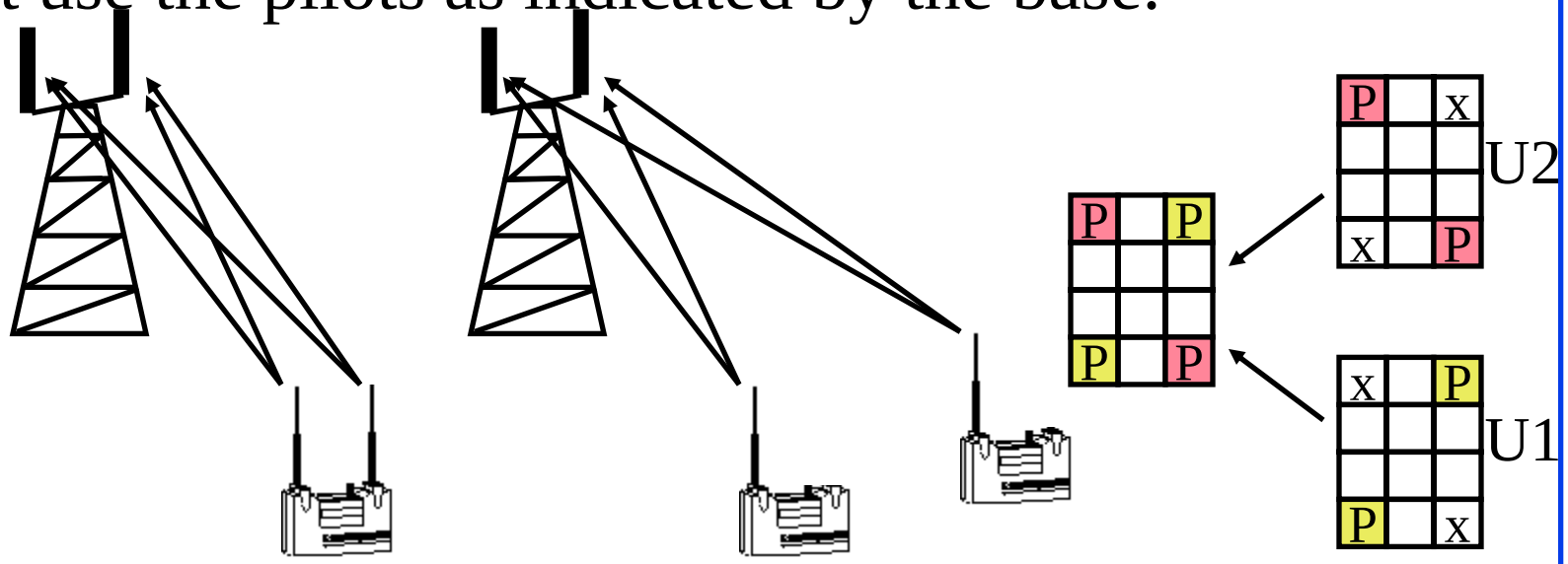
Source: International Telecommunication Union

Recent Advances in Wireless

1. Orthogonal Frequency Division Multiplexing (OFDM): Allows efficient use of wide channels (10-20 Mbps)
2. Time Division Duplexing (TDD): Allows asymmetric use of bandwidth (more downstream than upstream)
3. Multiple-Input Multiple Output (MIMO): Allows more bits/Hz by spatial reuse
4. Collaborative MIMO: Allows MIMO even when a user has only one antenna
5. Channel Bonding: Allows multiple spectrum bands to be used together $\Rightarrow$ Very high data rate

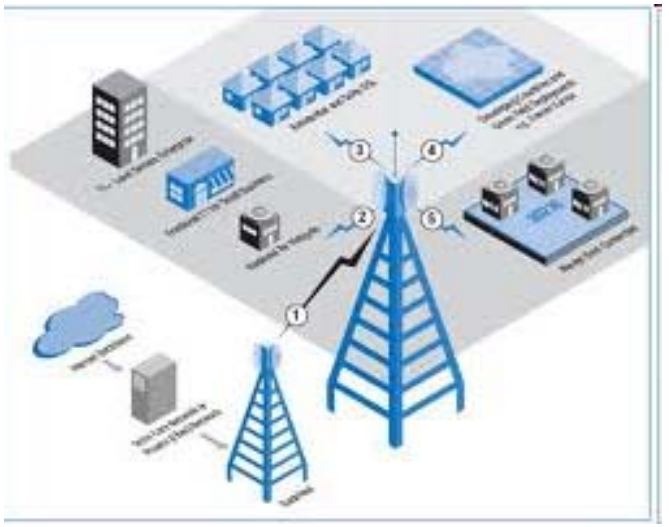
Cooperative MIMO

- Two subscribers with one antenna each can transmit at the same frequency at the same time
- The users do not really need to know each other. They just use the pilots as indicated by the base.



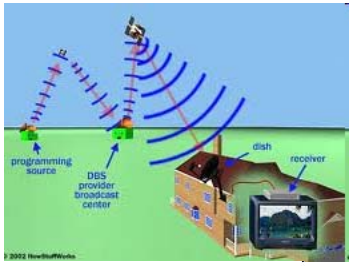
Oil and Gas Industry

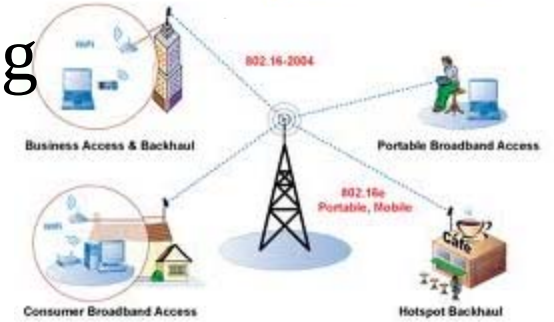
- Injection wells need to be monitored
- Broadband wireless access (BWA) allows a large field to be connected via a small number of base stations
- BWA networks are better suited than WiFi for given area to be covered
- Monitoring allows better planning and decision making



Deployment Scenarios

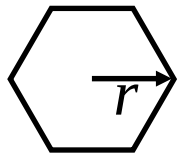
1. Fiber-to-X (FTTx) + DSL+WiFi: For Densely populated areas.
2. Satellite: Low rate and Long delay
   $\Rightarrow$ Only good for broadcast
3. WiFi: Short distance. Devices ubiquitous.
4. WiMAX/LTE: Good bandwidth and good coverage but devices emerging
5. WiMAX/LTE + WiFi: Best

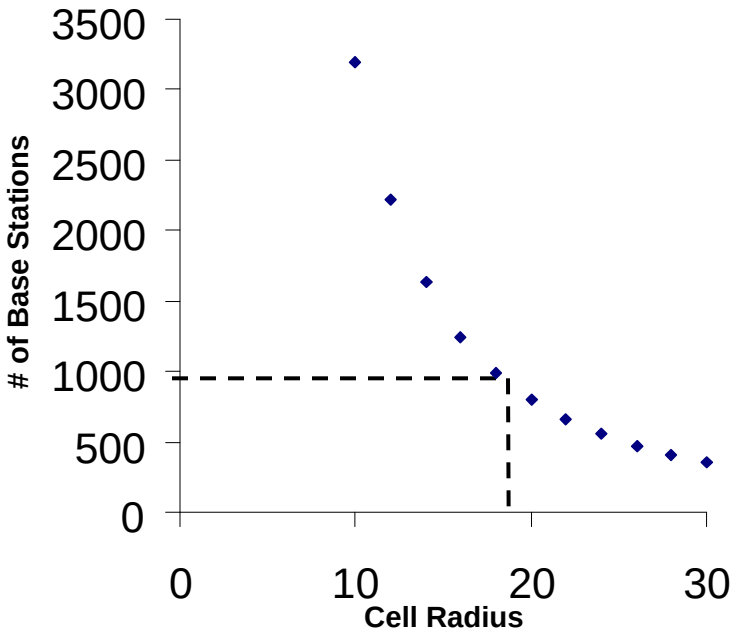


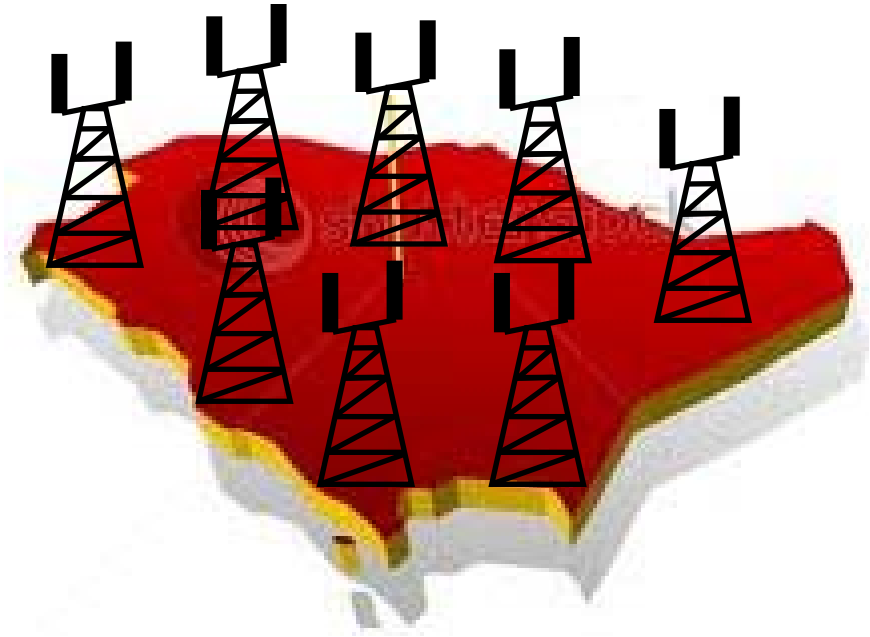


All-Wireless Network

- Saudi Arabia Area = 830,000 Sq miles
- Extending "Municipal Wireless" from WiFi to WiMAX
- One hexagonal cell of radius r covers $r^2 \frac{3\sqrt{3}}{2}$
- How many base stations are required to cover entire Saudi Arabia (an extreme scenario)? 986 if 18 mile radius





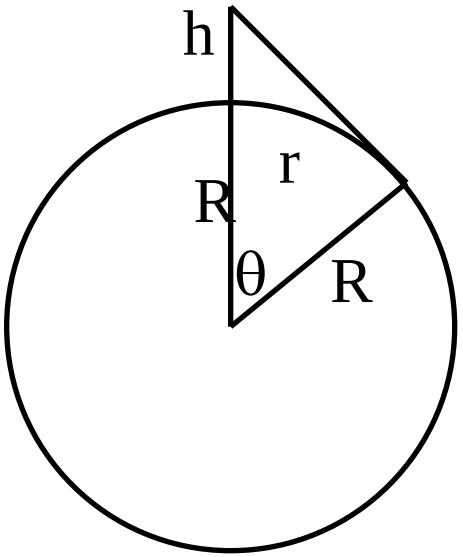


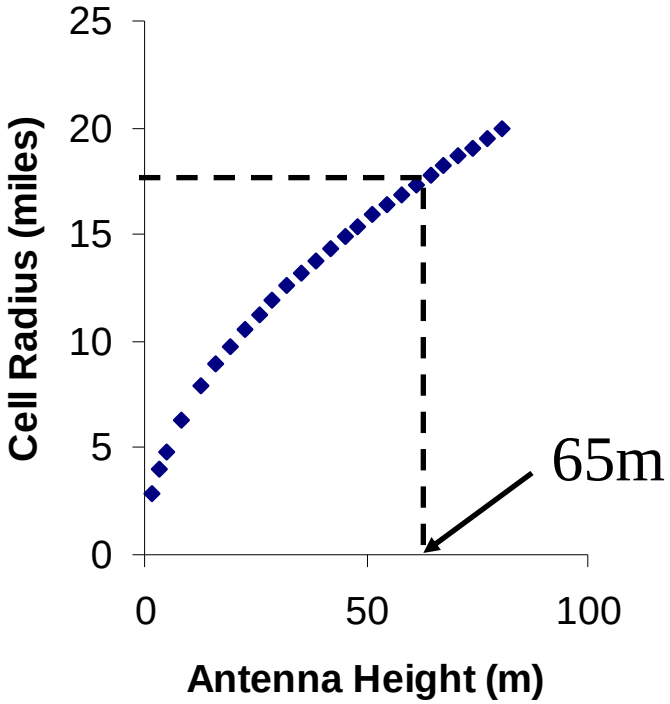
700 MHz Transmission

- Received Power $P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2$
- Path loss = (frequency $\times$ distance)^2
  $\Rightarrow$ Lower frequency allow larger cells
- 700 MHz will travel approx 5 times farther than 3.5 GHz
- 700 MHz is the spectrum used by television channels
- Analog TV channels require 6 MHz/Channel
  Digital TV channels require only 1 MHz/channel
  $\Rightarrow$ Lot of 700 MHz spectrum is being freed by digital TV
- This will be a good spectrum for broadband access over long distances

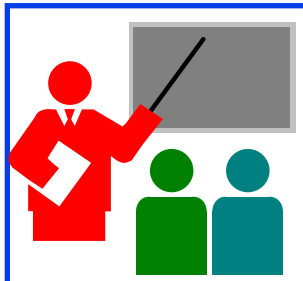
Tower Height

- Earth curvature limits distance an antenna can reach
- Height h gives a cell radius $r = R\cos^{-1}\left(\frac{R}{R+h}\right)$





Burj Khalifa in Dubai is 828m



Summary

1. Video Streaming is important for all aspects of living (better education, work, entertainment)
2. Research needs to be conducted at all layers of networking stack: Application, Transport, Network, MAC, PHY
3. Five Research Problems: Scheduling, Resource Prediction, Server Replication, User Mobility, Data Multihoming
4. New Broadband Wireless Access (BWA) technologies may offer a cost-effective solution for Saudi Arabia
5. BWA may also be ideal for oil and gas industry requiring outdoor long-distance communication
6. 400 MHz and 700 MHz spectrums offer good long-distance coverage only limited by earth curvature

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