Project	**IEEE 802.20 Working Group on Mobile Broadband Wireless Access** **<http://grouper.ieee.org/groups/802/20/>**
Title	**User Data Models for an IP-based Cellular Network**
Date Submitted	**2003-03-07**
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Re:	IEEE 802.20 Session#1 Call for Contributions
Abstract	This contribution provides data traffic models for IP traffic over cellular wireless networks.
Purpose	For informational purposes only
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User Data Models for an IP-based Cellular Network

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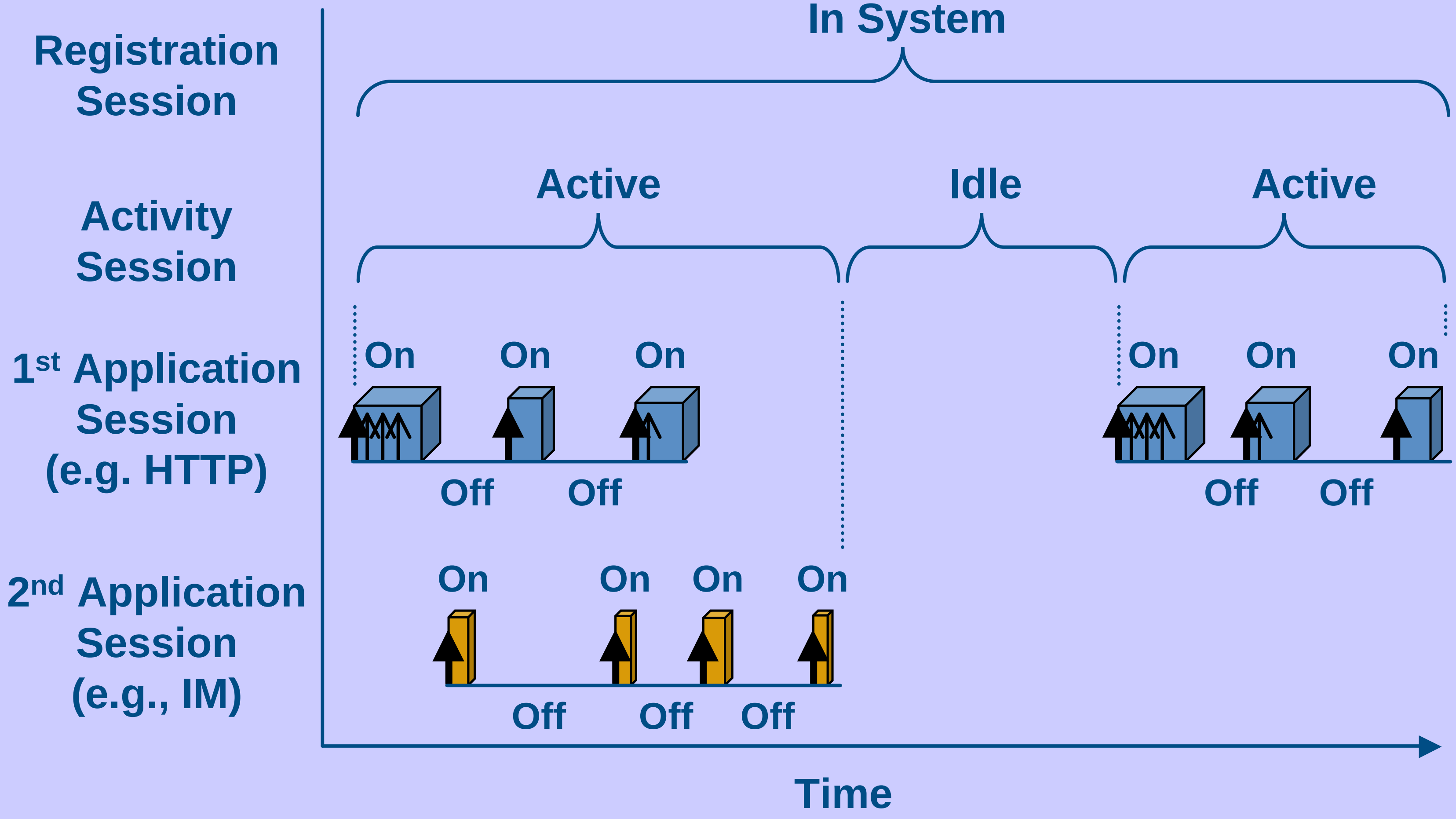
IEEE 802.20 MBWA

March 10-13, 2003

Where to begin?

- Define the problem space
- Limit the scope
  - Identify goals
  - Identify corresponding work to be done (e.g., particular system aspects to model)
- Develop models / adapt models from prior work
- Use models to support MBWA design

Sessions, Sessions and More Sessions



Registration Sessions

- Trend towards “always on” operation
- Potential core system dimensioning implications
  - Authentication, Authorization, Accounting servers
  - End system address allocation / routing
  - Paging servers
- Potential end system design implications
  - Power consumption (battery lifetime)
  - Need for sleep mode operation / page-ability
- Impact on MBWA design primarily in area of power consumption and paging mechanisms

Active Sessions

- Potential System Dimensioning Implications
  - Modeling of **traffic** characteristics during Active sessions provides insight regarding air-link parameters (e.g., number of concurrent users, MAC state transition times)
  - Modeling other characteristics of Active sessions (e.g., arrival / duration distributions) provides additional insights (e.g., for capacity planning)
- Modeling of Active sessions
  - Requires modeling of typical Application sessions
  - Active sessions may comprise multiple Application sessions

Application Sessions

- Modeling common Application sessions provides a good approximation to modeling Active sessions
  - Identify dominant applications
  - Assume **<u>non-overlapping</u>** Application sessions
- There are some relevant existing models from prior empirical studies

Approach

- Identify primary applications of interest
- Develop / adapt corresponding models
- Model **traffic** characteristics of Active session based on assumption of **non-overlapping** Application sessions
- Use to support air link design (e.g., parameter selection)

Traffic Characteristics from Wireless LAN Studies

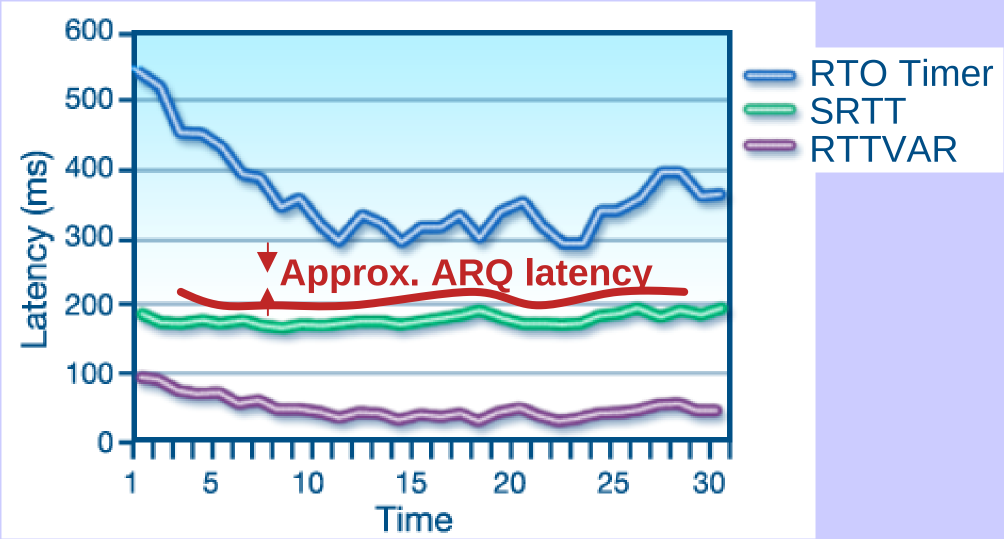
- TCP constitutes majority of traffic
  - 97.5% [1]
  - 91% [2]
- Slightly asymmetric in bytes transferred
  - 2:1 (Daily median) [1]
  - 3:1 (Total) [3]
- 80% of peak loads have 94% of traffic due to a single user and application [3] (qualitatively supported by [2] as well)

[1] D. Kotz and K. Essien, "Analysis of a Campus-wide Wireless Network," MOBICOM 2002.
[2] A. Balachandran et al., "Characterizing User Behavior and Network Performance in a Public Wireless LAN," SIGMETRICS, 2002
[3] D. Tang and M. Baker, "Analysis of a Local-area Wireless Network," MOBICOM 2000.

Effect of Packet Loss and Latency on TCP Throughput

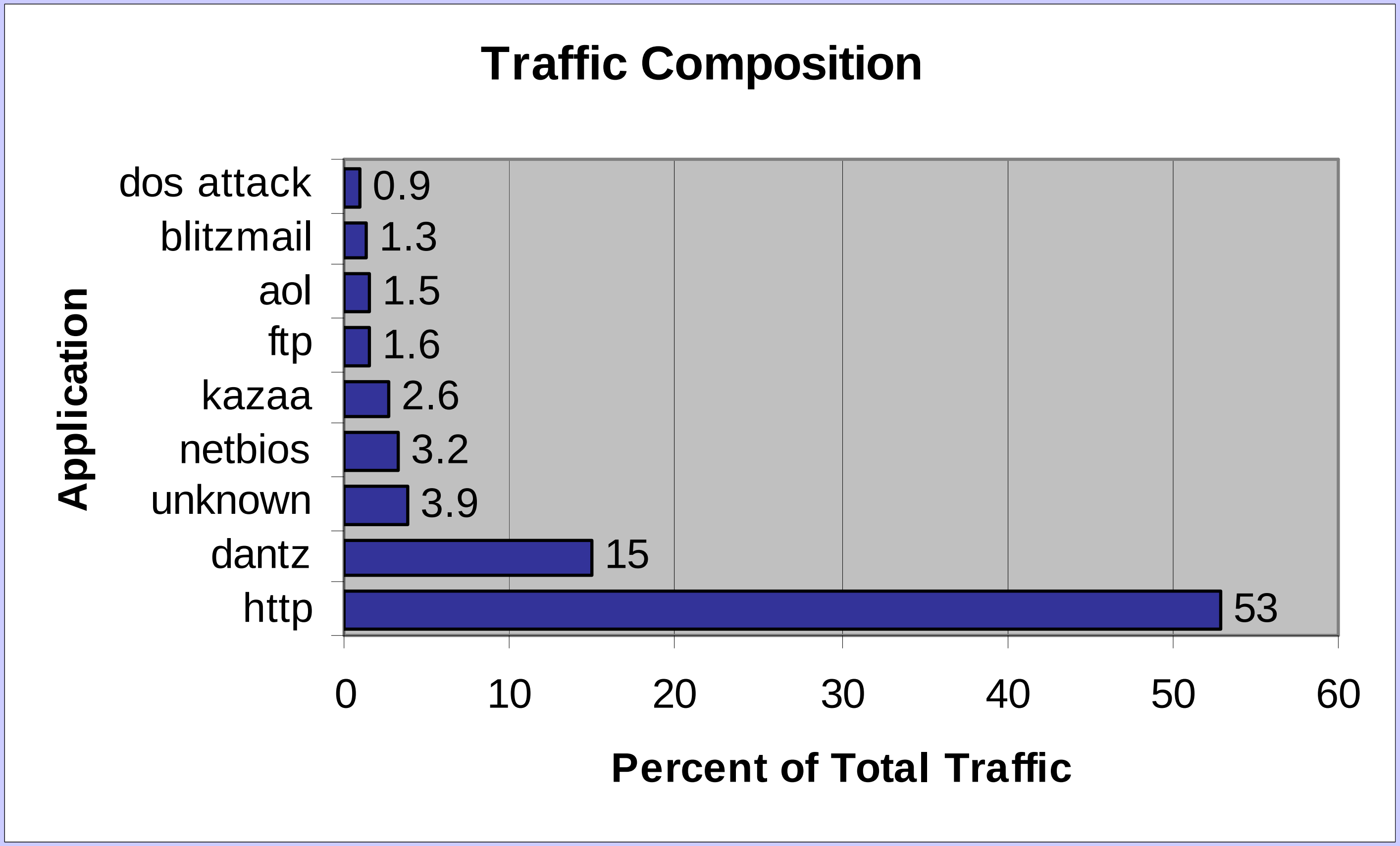
- TCP congestion control mechanisms “back-off” due to packet loss
- Large RTT and/or RTTVAR also reduce throughput

RTO Timer Evolution



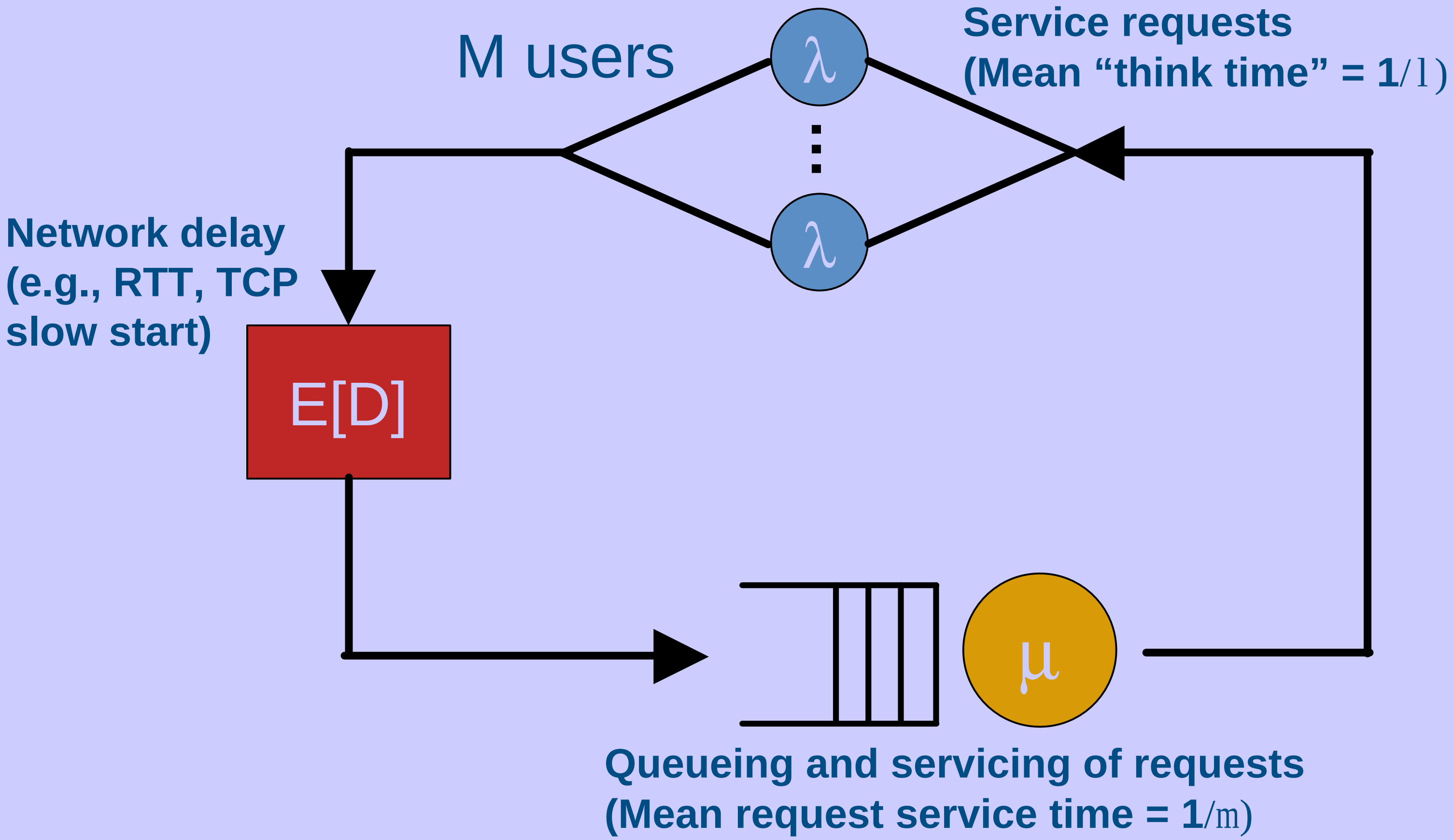
- Wireless links should ideally provide wire-like reliability without significant delays
- Implies any link-layer ARQ must have low loop delay

Example Traffic Composition from Trace of Dartmouth College WLAN



Source: D. Kotz and K. Essien, “Analysis of a Campus-wide Wireless Network,” MOBICOM 2002.

Modeling Interactive Application with Feedback (e.g., Web)



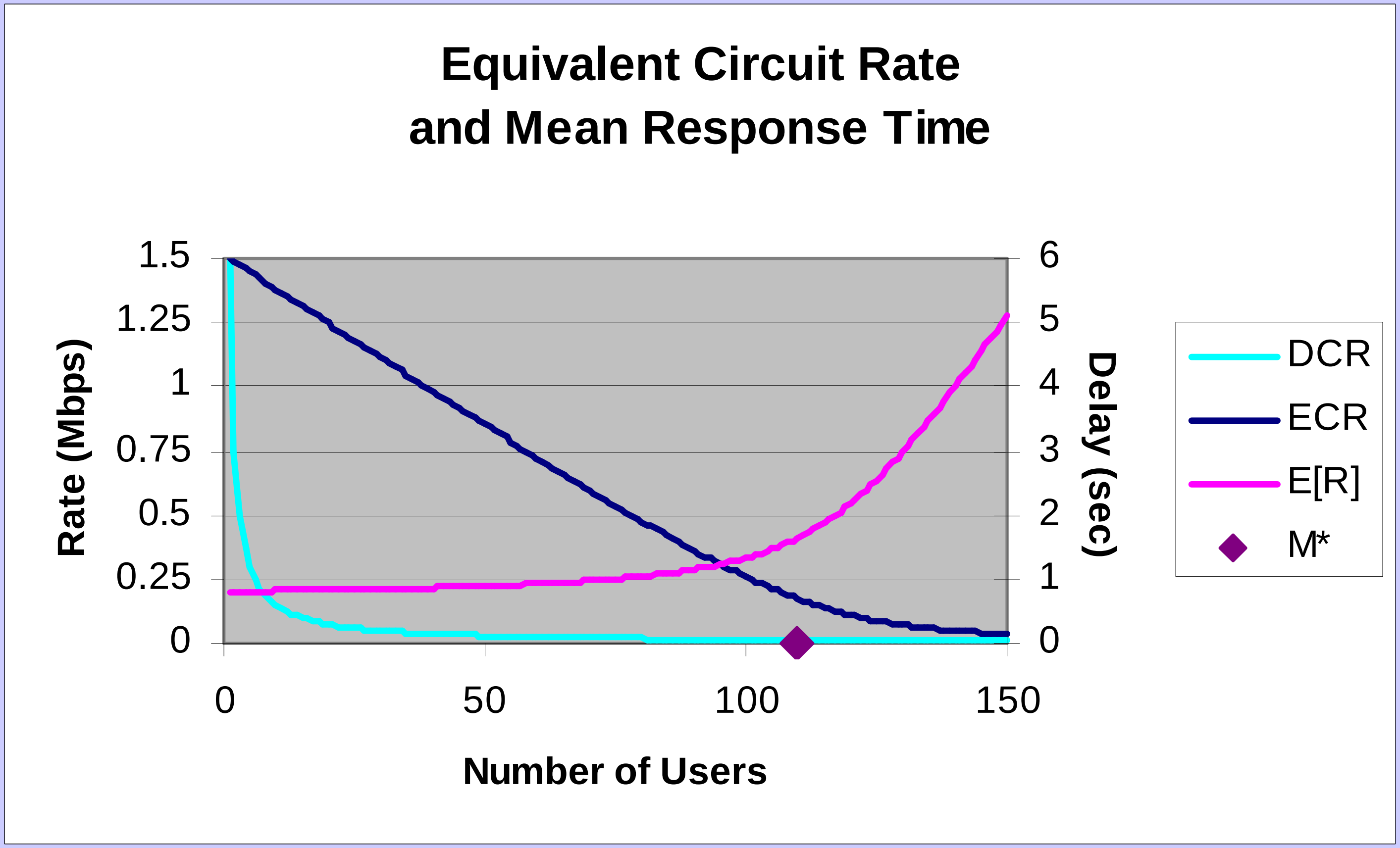
Source: N. Shankaranarayanan et al., "Performance of a Shared Packet Wireless Network with Interactive Data Users," http://www.research.att.com/areas/wireless/Mobile_Network_Performance/Shared_Channel/monet.pdf.

Modeling Web traffic

- Mean Page Request Size: 20 KBytes [4]
- Mean Think Time: 12 Sec [4]
- E[D]: 700 ms
  - RTT
  - TCP slow start
- User Workload: ~ 13.5 kbps

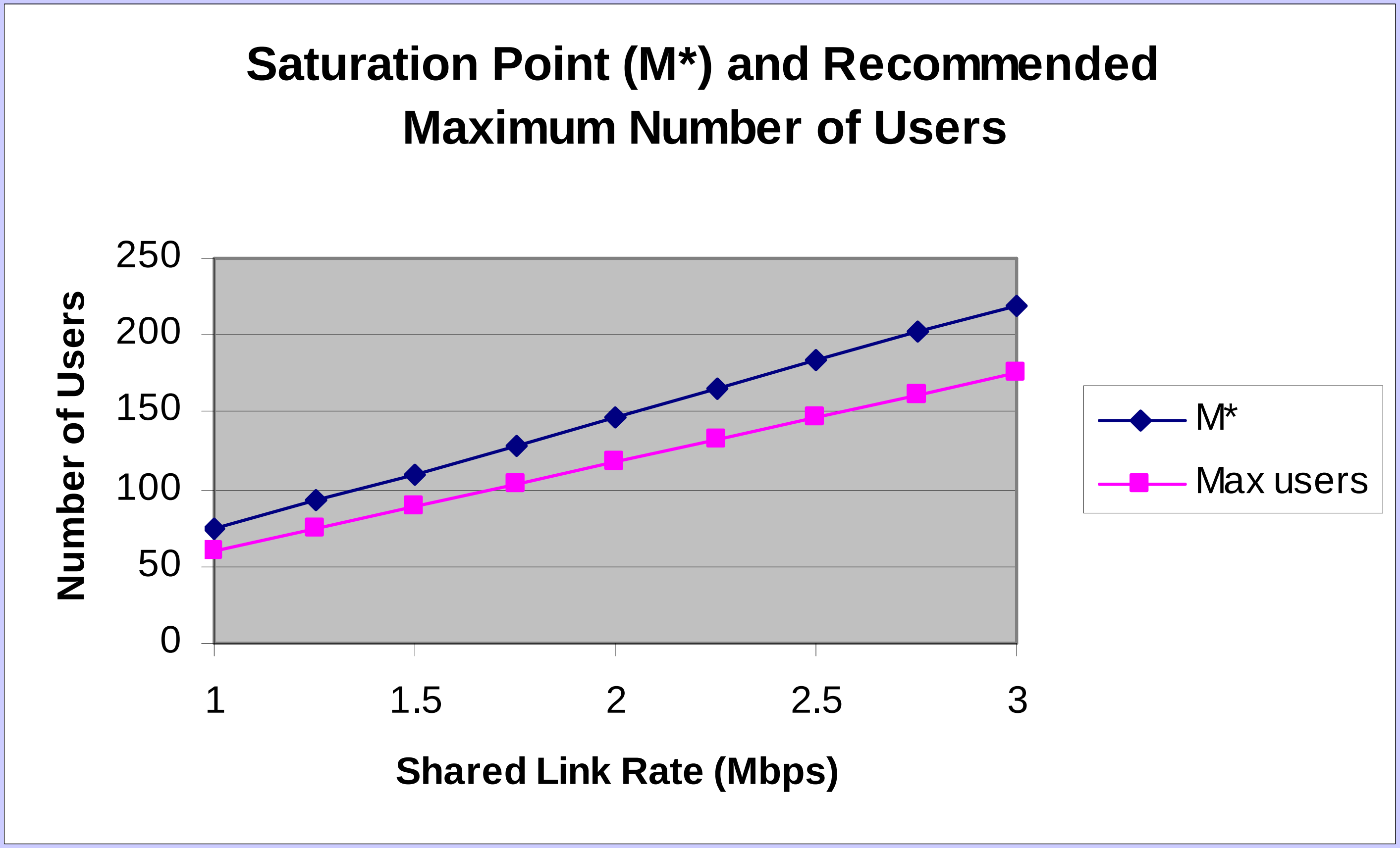
[4] N. Shankaranarayanan et al., “Performance of a Shared Packet Wireless Network with Interactive Data Users,” http://www.research.att.com/areas/wireless/Mobile_Network_Performance/Shared_Channel/monet.pdf.

Statistical Multiplexing Gain for 1.5 Mbps Shared Access Network



DCR: Dedicated Circuit Rate
ECR: Equivalent Circuit Rate
E[R]: Mean Response Time
M*: Saturation Point

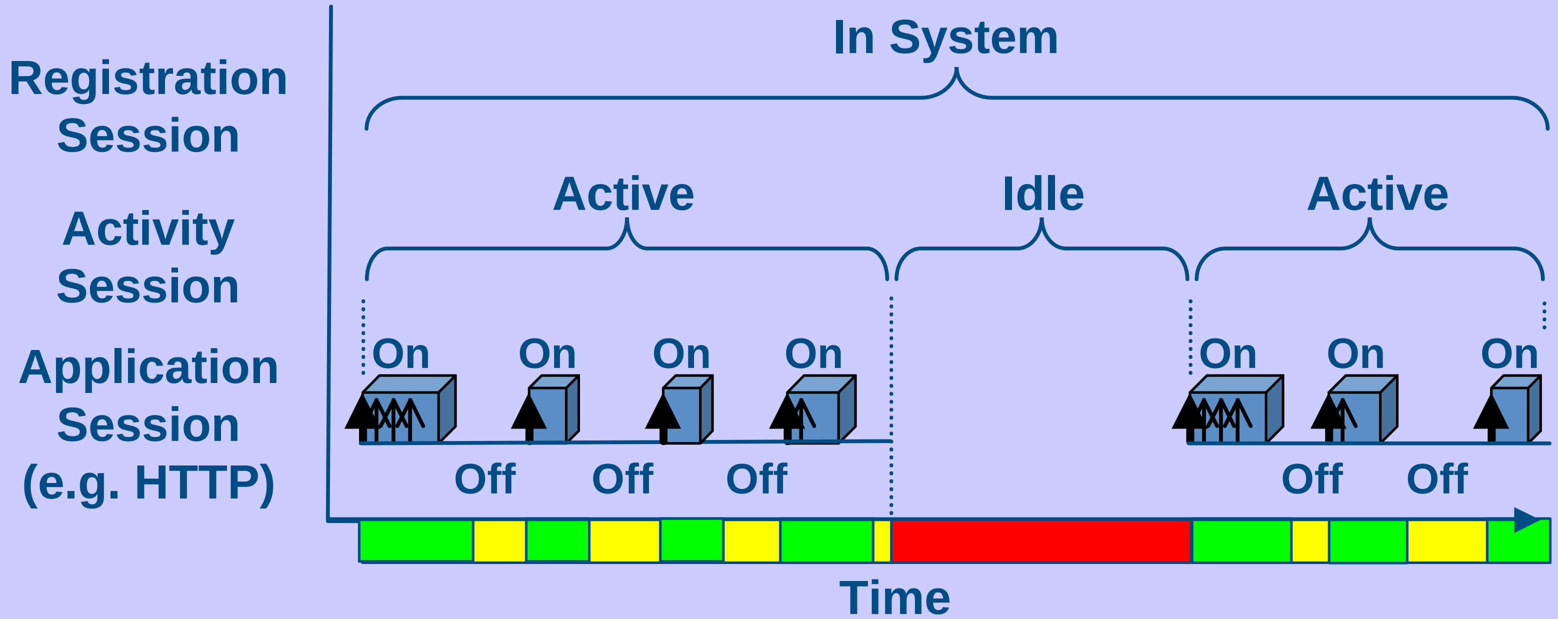
Number of Supported Users as a Function of Shared Link Rate



Number of Concurrent Active Users

- Modeling Web sessions alone indicates support for ~ **100** concurrent Active users is required to fully utilize shared link in the range of 1-2 Mbps
- Addition of other Active users running lower workload applications (e.g., VoIP, email, or IM) increases the requirement

User states



- Application Sessions have On/Off behavior
- Activity Sessions have Active and Idle periods
- From this, can classify users into three states:
  - "On" users – Application Session On
  - "Hold" users – Application Session Off
  - "Sleep" users – Idle period between Active Sessions

Benefits of User States

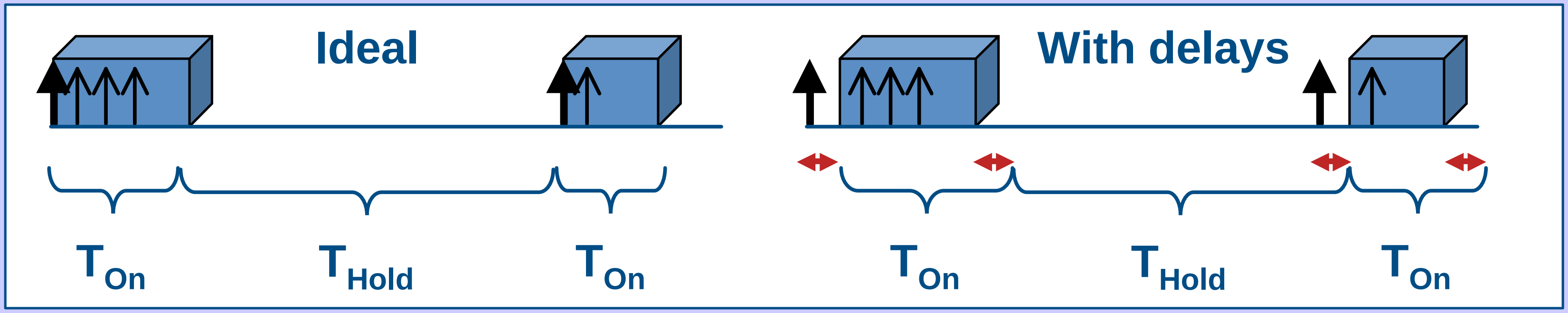
- Significant amounts of air link resources are required to enable users to actively send and receive traffic
  - e.g., for power control, timing control, traffic requests

- On state users – use full resources
- Hold state users – use reduced resources
- Sleep state users – use no resources

- Hold and Sleep states enable reduction of air link resources and mobile terminal power consumption
- *This allows the system to efficiently support large numbers of concurrent users (using "statistical multiplexing")*

State Transitions: Hold State

- Transitions between states require time and signaling resources
- Determine the requirements on state transition time based on Application session On/Off behavior and latency constraints



- Benefits of reducing state transition delay
  - On -> Hold: increases efficiency and statistical mux gain
  - Hold -> On: decreases latency and application response time
- Based on web traffic model
  - T_{On} ~ 1 sec, T_{Hold} ~ 12 sec
  - Indicates state transition times should be **< ~ 100 ms**
  - Smaller delays (Hold -> On) may be needed for real-time applications.

State Transitions: Sleep State

- Idle periods between Active sessions suggest Sleep state to enable power conservation while maintaining reachability
- Sleep -> On delay
  – Must support Application session establishment requirements (e.g., fast call set-up time)
    - User-perceived instant communications (e.g., PTT) require sub-second set-up times
    - Indicates Sleep -> On delay should be **< ~ 200 ms**
  – Corresponding requirement to support short page monitoring intervals (frequent paging schedules)

Summary

- DL/UL ratio should be reasonably symmetric
- TCP (HTTP) constitutes majority of traffic
  - Good performance requires reliability and low delay similar to wireline
- User data models indicate:
  - Need to support **> ~ 100** concurrent Active users
  - Benefits of 3 users states (On, Hold, Sleep)
  - Hold state transition delays **< ~ 100 ms**
  - Sleep to On transition delay **< ~ 200 ms**

Next Steps?

- Refine model of Active sessions to include overlapping Application sessions
- Model other characteristics of Active sessions (e.g., arrival / duration distributions)
- Adapt models based on evolving system specification