Proposal on Traffic Models

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Purpose:

This contribution was presented at the 2001 WCA Technical Symposium. BeamReach would like to submit this as a contribution to the ongoing efforts to determine a set of traffic models against which PHY/MAC proposals should be measured. BeamReach would like to present this to the group, and use this methodology as a basis for creating traffic models.

Traffic Models for Broadband Wireless Access Systems

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Market Environment

- Internet usage is increasing and migrating to broadband applications
- Many technologies vying to deliver broadband
  - Wireless, DSL, cable modem, satellite
- Operators searching for profitable business case to deliver broadband to residential and small business
- First generation fixed broadband wireless access systems are being deployed, but with limited capacity
- Next generation broadband wireless access technologies are being brought to market with improved performance, capacity, and cost

Modeling Concerns

- Voice-centric teletraffic engineering motivated by supporting a certain quality of telephone service, i.e., meeting a defined blocking probability and delay — Erlang models are the basis for analysis
- Data-centric traffic engineering concerns mirror those of teletraffic engineering, but no “Erlang” models exist — using a Poisson distribution is contrary to any observed data.
- Need to model Internet traffic at an access point
  - Need to define services of current and future interest, including amount of data transferred (data plus protocol overhead)
  - Need to consider dynamics of traffic flow
    - Flow control
    - Congestion
    - Routing
    - Throughput and latency of all connections

Internet Growth — Observations & Projections

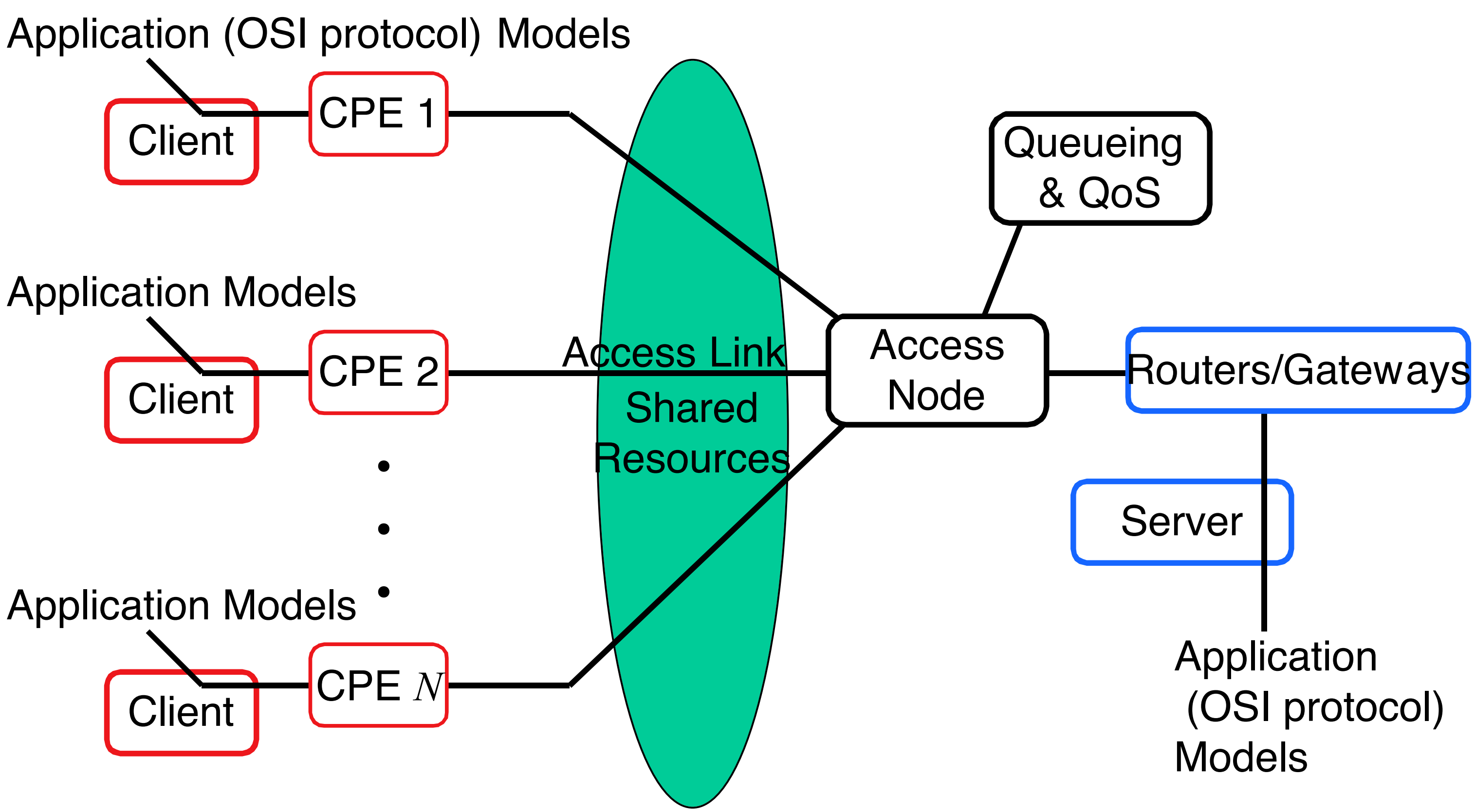
- More users
  - WWW introduced in 1996 – transition from e-mail
  - Assume future growth rate is 20 to 30% per year
- Longer connect times
  - Growing – 17 minutes per session (1997) to 35 minutes (1999)
  - Assume growth rate is 45% per year
- Applications
  - In 1997, user's average download rate was on the order of 1 kbps
  - Assuming rate is now 2.5 kbps to 4 kbps indicates growth rate of 10 to 40% per year
  - New applications (e.g., e-commerce, napster) will introduce variation
- Internet capacity
  - The Internet can move more data, but network delays are the largest component of transfer delay
  - Hard to predict roll-out of fiber and advanced server architectures

Problems with Observed Data

- Extrapolation is difficult – observed data is a snapshot in time
  - Number of users and their behavior
  - Personal computers (horsepower, browser technology, applications)
  - Routers (loading, delay), gateways, firewalls, number of hops
  - Servers (horsepower, locations)
- Loading/Congestion
  - Protocols can impact throughput significantly, and these protocols modify traffic flow in the presence of congestion
- The Internet is based upon a distributed architecture that makes it flexible and adaptable
- The growth of the Internet has been difficult to predict.

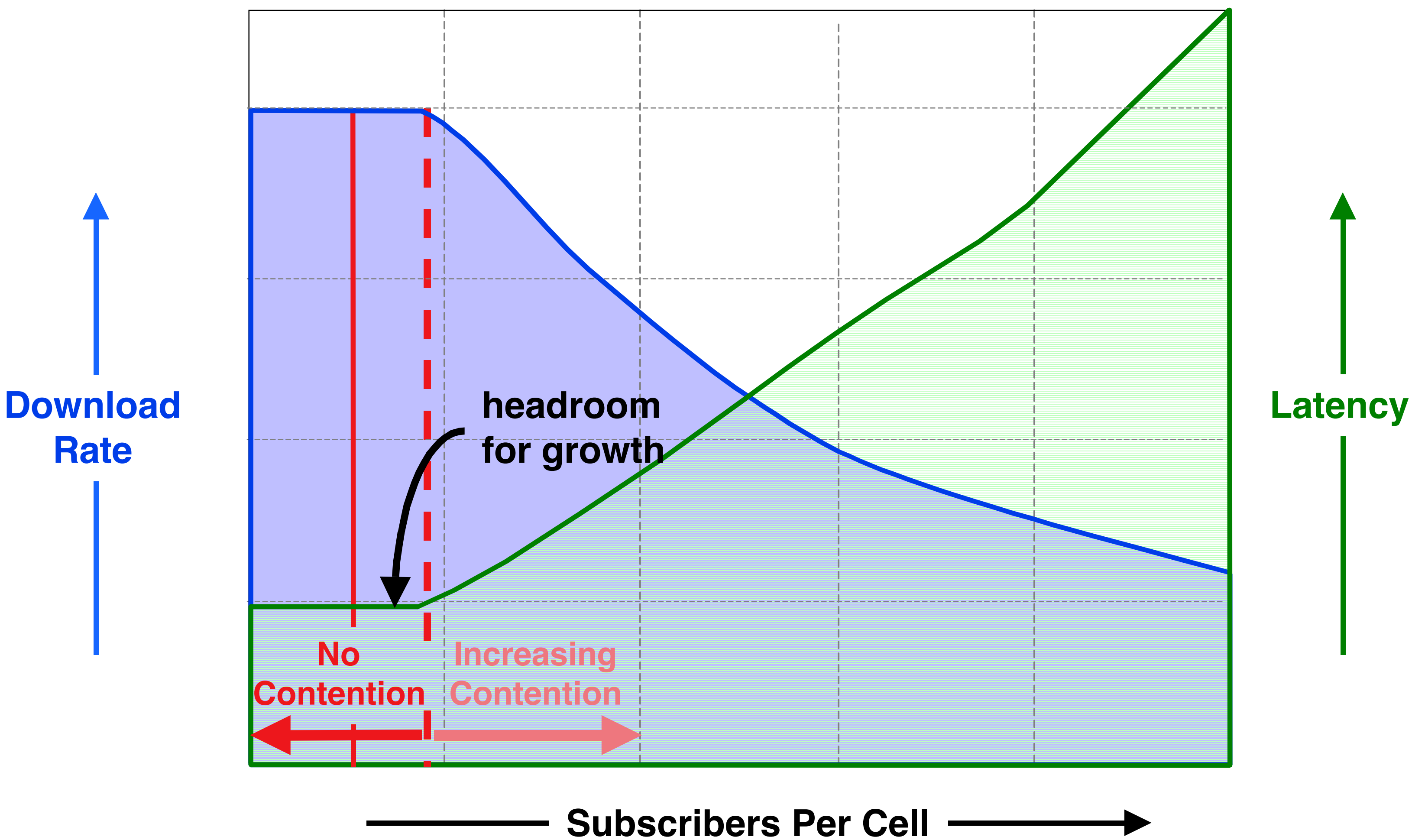
Observed data is used to generate parametric models that form the basis for simulations. Simulations are required to examine parameter dependencies and evaluate changes in loading (user and network) and usage.

Simulation Framework

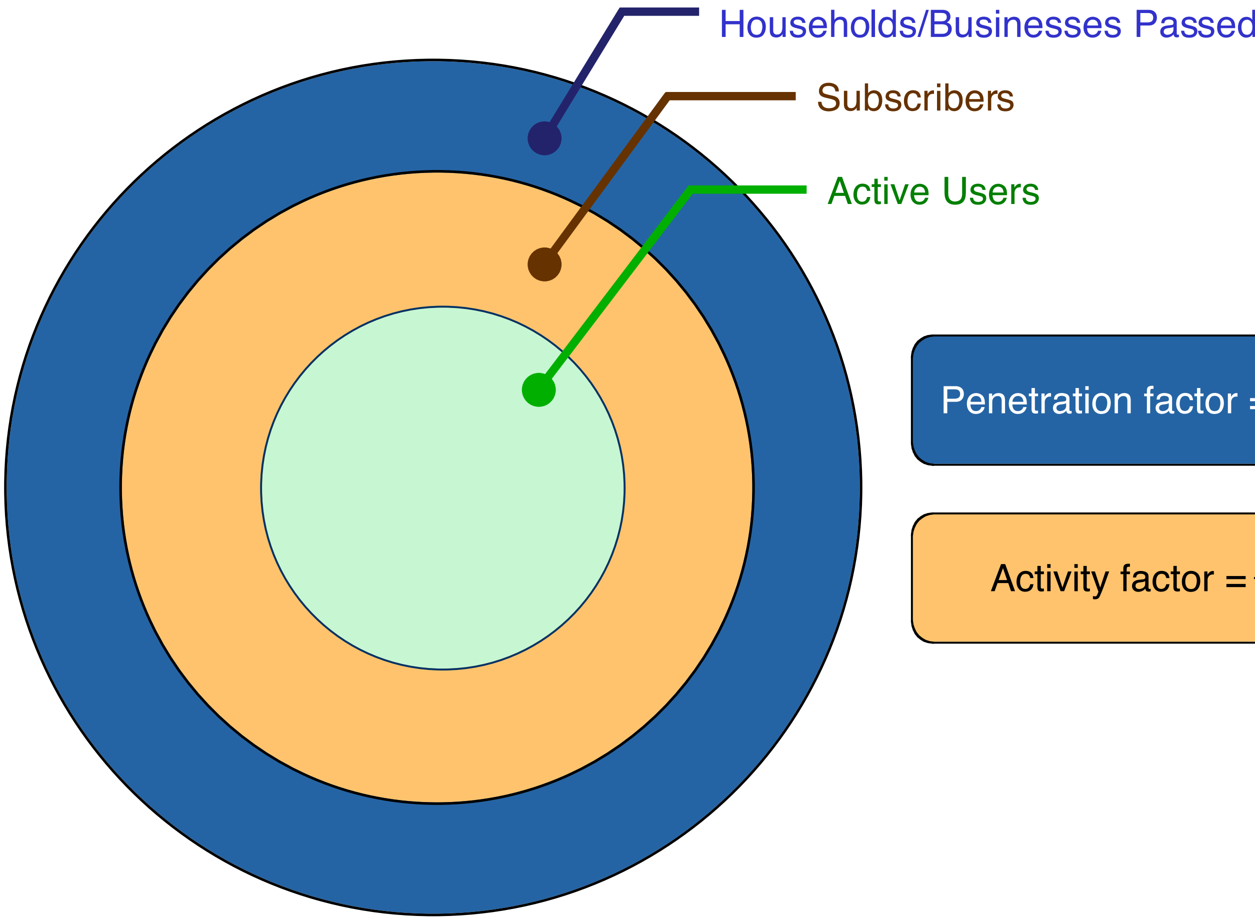


- Service providers need simulations to predict how much and what kind of equipment will be needed
- Equipment designers need simulations to understand performance under diverse loading scenarios, and predict equipment scalability

Throughput & Latency



Load Sizing



$$\text{Penetration factor} = \frac{\text{Subscribers}}{\text{Households}}$$

$$\text{Activity factor} = \frac{\text{Active users}}{\text{Subscribers}}$$

Characterizing Traffic Content

- Server logs
  - Servers tend to keep logs of their activity, but analysis is server specific and cannot capture user access patterns across multiple servers.
- Client logs
  - Client logs would be ideal if they existed. They could provide user access patterns across all servers, and could include the effects of client document caching. Although commercial companies have not implemented this type of logging in browsers, researchers have and could modify open-source browsers to capture information of interest.
- Packet traces
  - Packet traces on a subnet carrying Internet traffic are relatively easy to collect. Content models can be deduced by analyzing TCP/UDP protocols, tracking IP addresses, and making some general assumptions regarding usage of source/destination port addresses. The principal drawback is the difficulty in reconstructing a complete picture given multiplexed data. In addition, it is difficult to ascertain the effects of document caching since only cache misses are present.

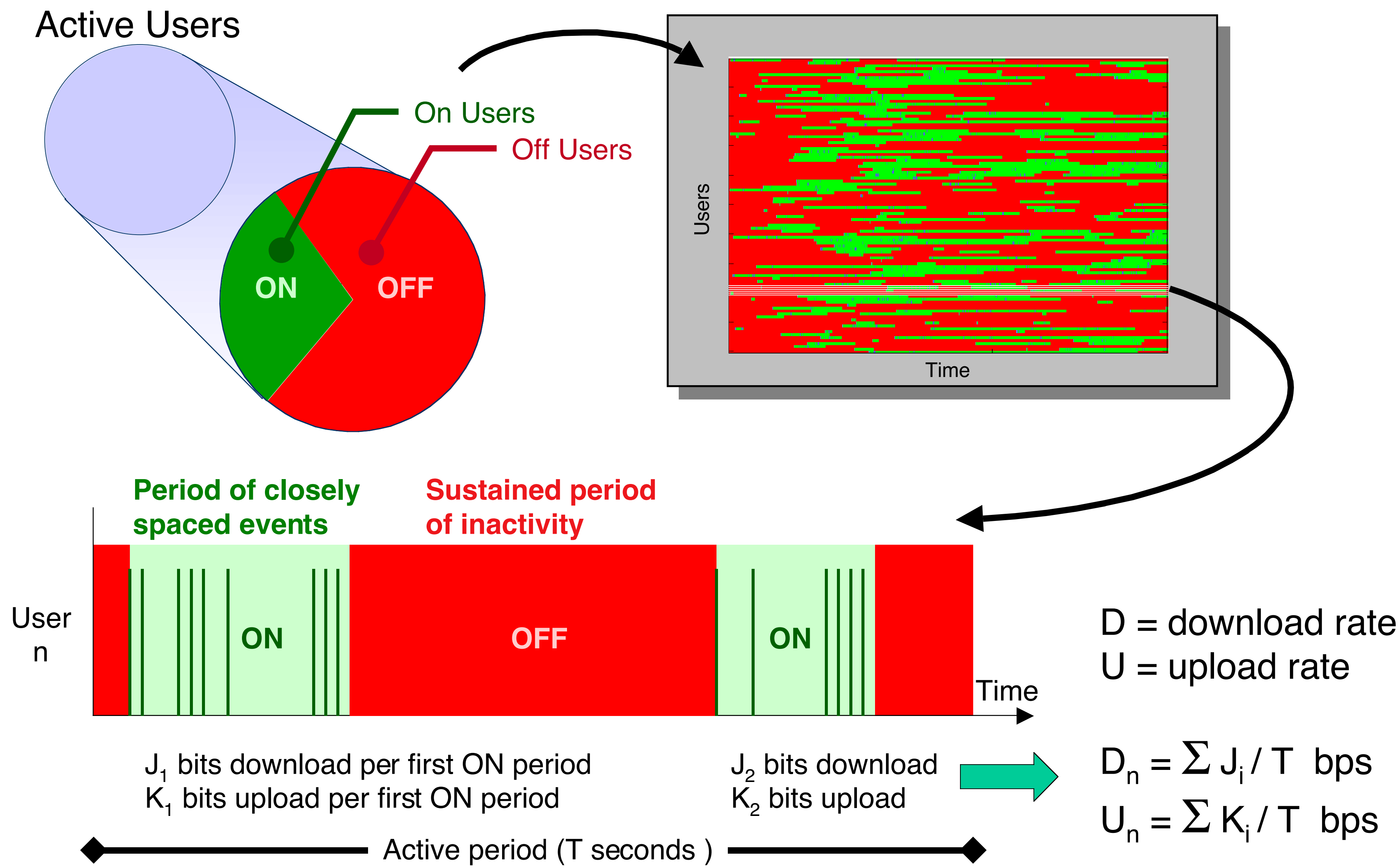
Results from Packet Traces

- Prevalent applications and protocols
  - HTTP is the dominant application
  - TCP can contribute significantly to the percentage data flow
- Flow and session durations, volumes, and bit rates
  - Durations can be modeled by heavy-tailed distributions (Pareto, Weibull)
- Numbers and sizes of objects making up a web page
  - Objects are modeled by a Pareto distribution
- Number of consecutive web pages
  - Modeled by exponential distribution
- Downstream/upstream ratios
  - Data services tend to be asymmetric; HTTP moving towards 3:1
  - Communication services are symmetric: VoIP, video conferencing
- Network delays

ON/OFF Models

- ON/OFF Model
  - Simulates the bursty behavior of a process
  - Information is transferred within a succession of ON periods separated by inactive OFF periods
- Specific ON/OFF Models
  - Data: Deng; Molina, Castelli, Foddis
  - Streaming services: Interrupted Poisson Process (IPP)
    - Special case of ON/OFF model where the ON/OFF periods and interarrival rate during the ON period are mutually independent Poisson processes.
  - Streaming services: Markov Modulated Poisson Process (MMPP)
    - Generalization of the IPP where arrivals occur in a Poisson manner with a rate that varies according to a k-state Markov chain.
    - MMPP reduces to IPP when k = 2 and the packet rate during the OFF period is 0.

Average Data Rates



Service Mixtures – Residential

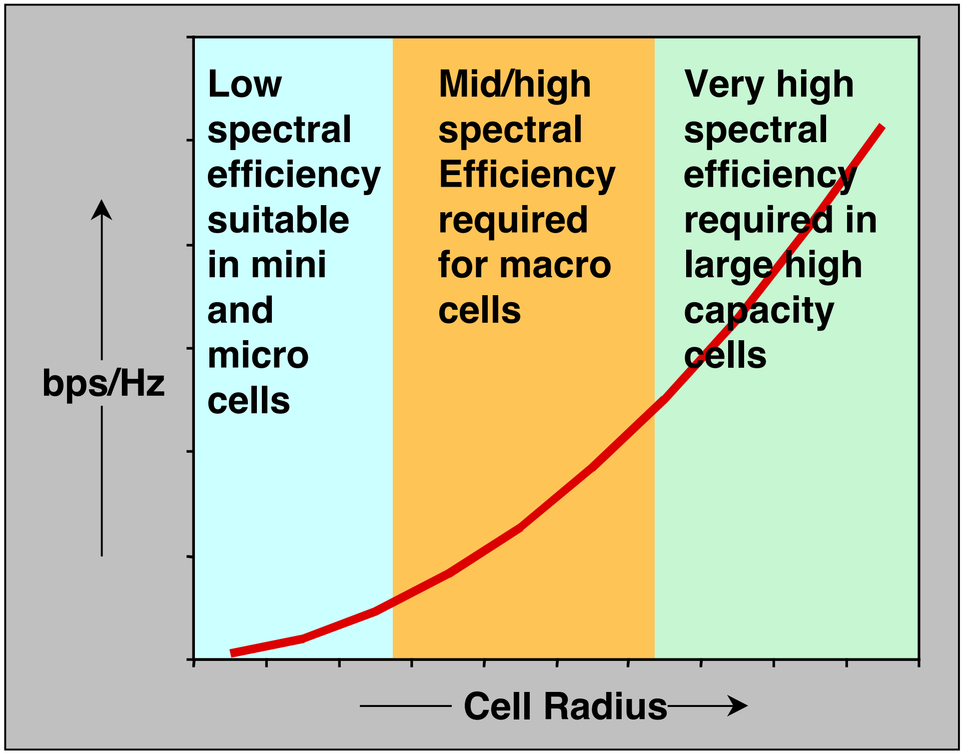
	Current		Future	
	Downlink	**Uplink**	**Downlink**	**Uplink**
HTTP				
Page Size (kbytes)	40	5	70	10
Pages/Minute	0.5	0.5	2	2
Bandwidth/User (kbps)	2.7	0.3	23	13
% Traffic	92.5%	92.5%	80.0%	80.0%
FTP				
File Size (kbytes)	200	100	1,000	100
Files/Minute	1	1	1	1
Bandwidth/User (kbps)	27	3.0	135	70
% Traffic	5.0%	5.0%	5.0%	5.0%
Streaming Audio				
Codec Rate (kbps)	32	2	32	2
Bandwidth/User(bps)	37	3	37	3
% Traffic	2.5%	2.5%	10.0%	10.0%
Streaming Video				
Codec Rate	23	0.03	128	0.13
Bandwidth/User (kbps)	27	0.03	150	75.00
% Traffic	0.0%	0.0%	5.0%	5.0%
Aggregate User Rate (kbps)	5	0.5	36	18

Usage Scenarios

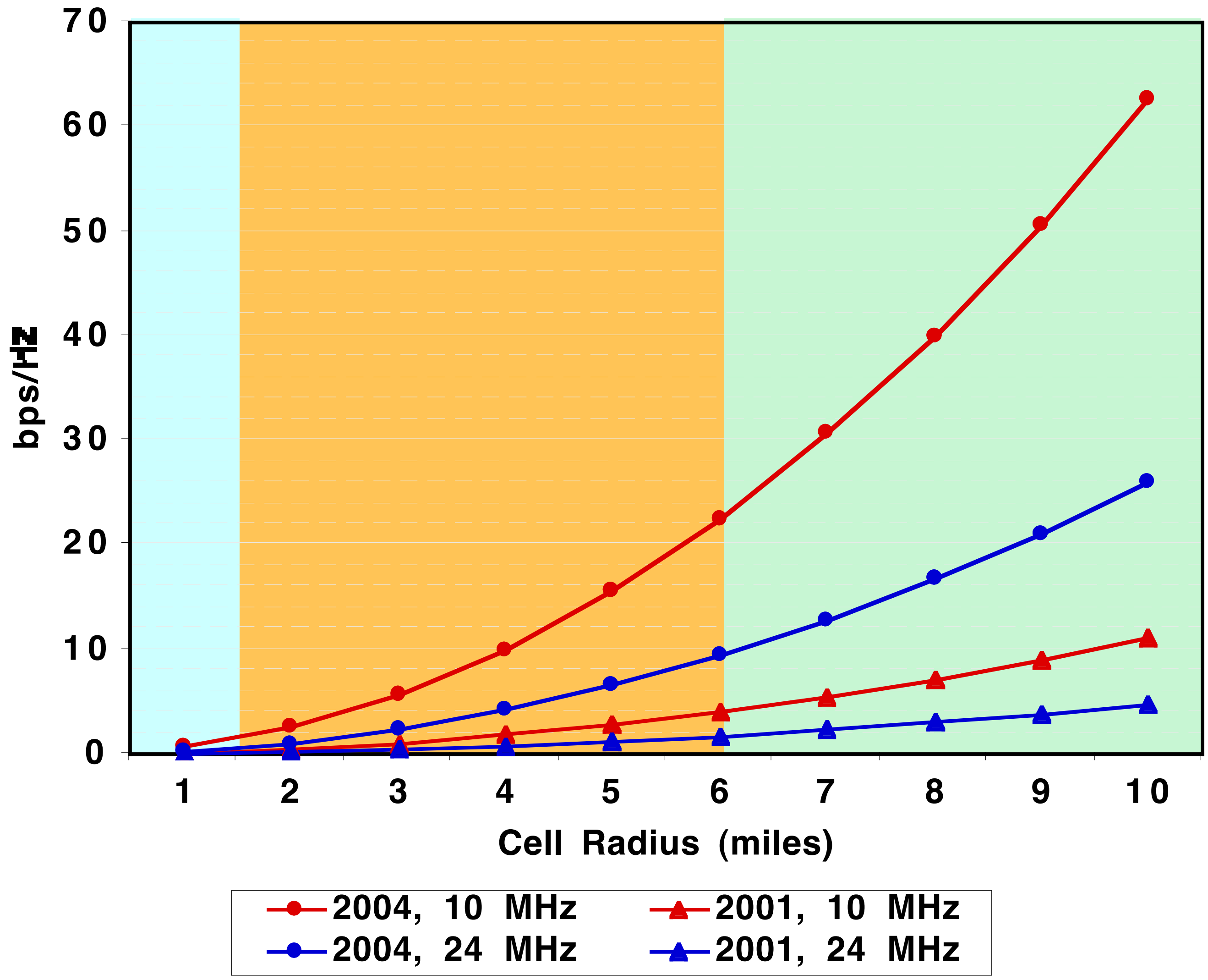
	1999	2001	2004
Residential			
D/U ratio	10	5	2
Average download rate (kbps)	5	10	36
Average upload rate (kbps)	0.5	2	18
Activity	8%	12%	18%
SOHO (1-10 employees)			
D/U ratio	5	5	2
Average download rate (kbps)	14	27.4	75.3
Average upload rate (kbps)	2.8	5.5	37.7
Activity	10%	15%	25%
Small Business (10-50)			
D/U ratio	2	2	1
Average download rate (kbps)	50	98	269
Average upload rate (kbps)	25	49	269
Activity	15%	25%	40%
Medium Business (50-250)			
D/U ratio	2	1.5	1
Average download rate (kbps)	100	196	538
Average upload rate (kbps)	50	131	538
Activity	25%	35%	50%

Spectral Efficiency Impact

- High spectral efficiency allows use of narrow spectrum bands to develop a viable service
- As broadband traffic demands grow, spectral efficiency becomes a key factor in business case decisions (base station and site acquisition/maintenance costs)
  - Low spectral efficiency
    - mini/micro deployment
  - Mid/high spectral efficiency
    - macro deployment
  - Very high spectral efficiency
    - super-cell deployment



Spectral Efficiency Requirements



Conclusions

- Traffic models are required by service operators and equipment manufacturers; seemingly small variations can result in significant deviations
- Predicting/tracking growth requires detailed simulations based on statistical models
- Broadband wireless access systems need to support high spectral efficiency to support reasonable service penetration economically
- First generation fixed wireless technologies will either not be able to support the anticipated broadband traffic requirements or will require too many base stations to be cost effective
- Operators will need to look to advanced BWA technologies to successfully deploy a competitive wireless broadband offering

References

- Kevin Thompson, Gregory Miller, Rick Wilder, “Wide-Area Internet Traffic Patterns and Characteristics (Extended Version), ” abridged version appears in IEEE Network, November/December 1997.
- k claffy, G. Miller, K. Thompson, “the nature of the beast: recent traffic measurements from an Internet backbone,” Proceedings of INET ‘98 Conference, April 1998.
- Paul Barford, Azer Bestavros, Adam Bradley, Mark Crovella, Computer Science Dept. Boston University, “Changes in Web Client Access Patterns”, in World Wide Web, Special Issue on Characterization and Performance Evaluation.
- M.E. Crovella, A. Bestavros, “Self-similarity in World Wide Web traffic: evidence and possible causes, IEEE/ACM Trans. Network,” 1997, pp. 835-846.
- Bruce A. Mah, “An Empirical Model of http Network Traffic,” in Proceedings of INFOCOM ’97, Kobe, Japan, April 1997.

References (2)

- J. Charzinski, “HTTP/TCP connection and flow characteristics,” Performance Evaluation, 42, 2000, pp. 149-162.
- S. Deng, “Empirical Model of WWW Document Arrivals at Access Link”, Proceedings of the 1996 IEEE International Conference on Communications, pp. 1797-1802.
- M. Molina, P. Castelli, G. Foddis, “Web Traffic Modeling Exploiting TCP Connections’ Temporal Clustering through HTML-REDUCE,” IEEE Network, May/June 2000, pp. 46-55.
- P. Sevcik, “Planning Your Intranet-Internet Connection,” Business Communications Review, January 1997, pp. 32-35.
- P. Sevcik, “The Myth of Internet Growth,” Business Communications Review, January 1999, pp. 12-14.