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802.20 Evaluation Methodology

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Outline

- Goal and motivation.
- Channel Models.
- DL Traffic Models.
- Summary.

Goal and Motivation

- Develop an **evaluation methodology** that includes a set of definitions, assumptions, models, and a general framework for simulating technology proposals to 802.20.
- **"Evaluation Methodology"** along with **proposal details** would enable others to duplicate their results.
- An evaluation methodology would help us be sure that:
  - We've met the PAR
  - We have baselined against other technologies correctly
  - We have built consensus that we're developing the best technical solution.
- **Examples:**
  - 3GPP2 1xEV-DV Evaluation Methodology.
  - W-CDMA HSDPA technology simulation proposal R1-030115.

Evaluation Methods

- **Link level** methods **are not adequate** to capture the richness and dynamics of a system with multiple access points and terminals

- Need a **combination** of **link level** and **system level** methods:
  - **System level:** model coverage area, propagation conditions for each link, captures the fading dynamics based on the shortest control process in the system (e.g. a power control period in WCDMA)
  - **Link level:** map the resulting E_b/N_t on each link every update interval and evaluate the resulting error measures using link level curves.

Evaluation Methods (cont'd)

- System Simulation: **two phases**
  - Phase I: different mixture of services (**voice only**, voice + data, and data only). Would include physical layer HARQ and signaling errors.
  - Phase II: includes TCP and upper layers for data services
- Parameter set (different for each link).
  - Example: typical parameter set for DL:
    - # cells (sectors)
    - cell size
    - antenna pattern and orientation
    - propagation model
    - base station antenna correlation
    - Tx and Rx antenna gains
    - thermal noise model
    - carrier frequency
    - power control
    - etc.

Things to Consider

- Fading and propagation models
- DL Traffic models:
  - Web browsing, ftp, video, and voice
  - Different traffic models for UL and DL
  - Effects of TCP

Channel Models

- Three basic environments: path loss, shadowing, and delay profile model.
  - **Indoor** Environment
  - **Pedestrian** and Outdoor to Indoor Environment
  - **Vehicular** Environment.

- Each delay profile model has two variations:
  - **"A" model:** low delay spread case that happens frequently.
  - **"B" model:** median delay spread case that also happens frequently.

Fading and Propagation Models

- Different fading components:
  - Mean **path loss** model:
    - A deterministic model. Function of distance between Tx and Rx, antenna heights, carrier frequency, and the terrain.

$$L = \phi\left(f, R, h_a, h_b, \ldots\right)$$

  - **Shadowing** model: models the effect of blocking, diffraction, etc. A statistical model.

Distribution	Normal in dB	σ_s
Decorrelation Model (emp)	$R(\Delta x) = e^{\alpha\lvert\Delta x\rvert / x_d}$	x_d

  - **Fast fading** and **delay spread** models: number of paths, their delays and power profile, Doppler spectrum, and assignment probability.

Indoor Environment

- Small cell size and low transmit power
- Tx and Rx are located indoors.
- Very small Doppler values (walking speeds).
- Lots of scattering structures.
- Path loss Model

$$L = 37 + 30\log_{10}(R) + 18.3n^{((n+2)/(n+1)-0.46)}$$

R distance between Tx and Rx

n number of floors in propagation path

- Shadowing: σ_s = 12 dB.
- Worst case scenario from an interference point of view.

Indoor Environment (cont'd)

Tap	Channel A		Channel B		Doppler Spectrum
	Relative Delay (nsec)	Average Power (dB)	Relative Delay (nsec)	Average Power (dB)	
1	0	0	0	0	Flat
2	50	-3.0	100	-3.6	Flat
3	110	-10.0	200	-7.2	Flat
4	170	-18.0	300	-10.8	Flat
5	290	-26.0	400	-18.0	Flat
6	310	-32.0	700	-25.2	Flat

Delay Power Profile for Indoor Environment

Pedestrian Environment

- Small cell size and low transmit power.
- BS with low antenna heights are located outdoor; with a mixture of indoor and outdoor users.
- Doppler rates are mainly small at walking speeds with occasional higher rates due to reflections from moving vehicles.
- Average building penetration loss of 12 dB with a standard deviation of 8 dB.
- Shadowing: σ_s = 12 dB for indoor and σ_s = 10 dB for outdoor.

Pedestrian Environment (cont'd)

- Path Loss Model I: describes worst case propagation. Used for coverage prediction.

$$L = 40\log_{10}(R) + 30\log_{10}(f) + 49$$

R Distance between Tx and Rx

f carrier frequency

- More accurate model, assumes urban environment (Manhattan distances)

$$L = 20 \cdot \log_{10} \frac{4\pi d_n}{\lambda}$$

d_n effective Manhattan distance

λ wavelength

n number of street segments

- Can be extended to cover dual slop behavior.

Pedestrian Environment (cont'd)

Tap	Channel A		Channel B		Doppler Spectrum
	Relative Delay (nsec)	Average Power (dB)	Relative Delay (nsec)	Average Power (dB)	
1	0	0	0	0	Jakes
2	110	-9.7	200	-0.9	Jakes
3	190	-19.2	800	-4.9	Jakes
4	410	-22.8	1200	-8.0	Jakes
5	-	-	2300	-7.8	Jakes
6	-	-	3700	-23.9	Jakes

Delay Power Profile for Pedestrian and Outdoor to Indoor Environment

Vehicular Environment

- Large cell size and high transmit power
- BS with antennas at roof tops. Users are a mixture of pedestrian, stationary, and vehicular.
- Doppler rates are set by the vehicular speeds with occasional rates for stationary users.
- Path loss:

$$L = 40\left(1 - 0.004 \times \Delta h_b\right)\log_{10}(R) - 18\log_{10}\left(\Delta h_b\right) + 21\log_{10}(f) + 80 \text{ dB}$$

R distance between Tx and Rx

f carrier frequency

Δh_b BS antenna height above roof top (0-50 meters)

- Valid for NLOS and represents worst case.
- Shadowing: σ_s = 10 dB.

Vehicular Environment (cont'd)

Tap	Channel A		Channel B		Doppler Spectrum
	Relative Delay (nsec)	Average Power (dB)	Relative Delay (nsec)	Average Power (dB)	
1	0	0	0	-2.5	Jakes
2	310	-1.0	300	0	Jakes
3	710	-9.0	8900	-12.8	Jakes
4	1090	-10.0	12900	-10.0	Jakes
5	1730	-15.0	17100	-25.2	Jakes
6	2510	-20.0	20000	-16.0	Jakes

Delay Power Profile for Vehicular Environment

Shadow Fading Decorrelation

- Gudmundson: measurement based in urban and sub-urban (more accurate):

$$\rho(\Delta x) = e^{-0.69315.|\Delta x| / x_c}$$

x_d decorrelation distance

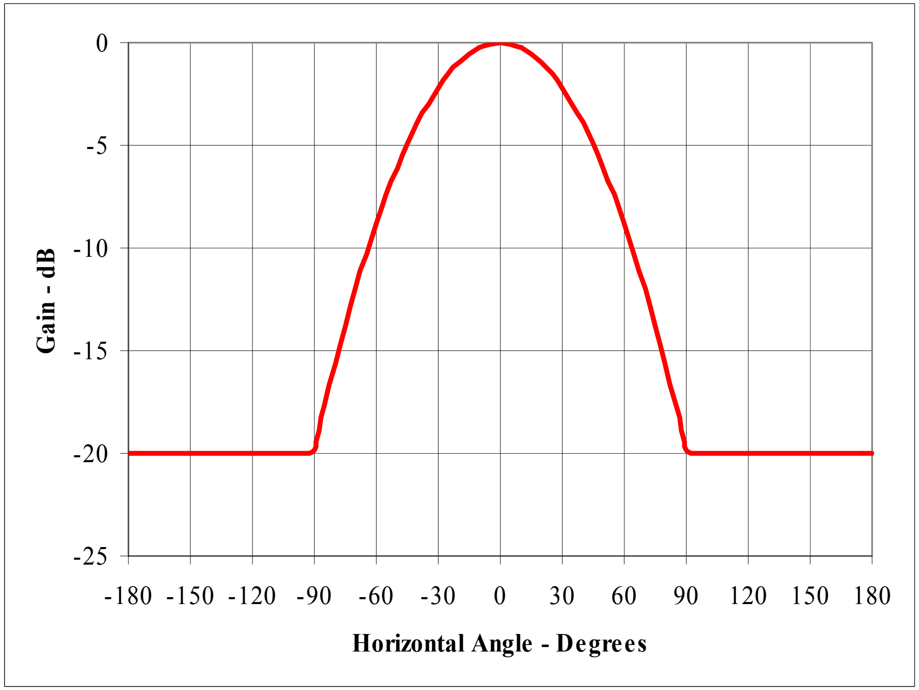
- D. Cox: for urban environment with large number of high rises, shadowing process is better modeled as an independent increment process with increment durations approx. 1 city block.

Antenna Pattern for Sectorization

$$A(\theta) = -\min\left\{12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right\} \qquad -180 \le \theta \le 180$$

θ_{3dB} is the 3 dB beamwidth

A_m is the maximum attenuation



Traffic Models

- Different mixtures of users: voice only, voice+data, and data only
- Voice traffic models:
  - Voice codec
  - Circuit-switched or VoIP
  - In general, a Markov source with different rates (full rate, half rate, etc) with a corresponding set of transition probabilities between different rates
  - Voice capacity is obtained based on satisfying a certain outage criteria (or a group of); e.g, short term FER, per user outage, and/or system outage.

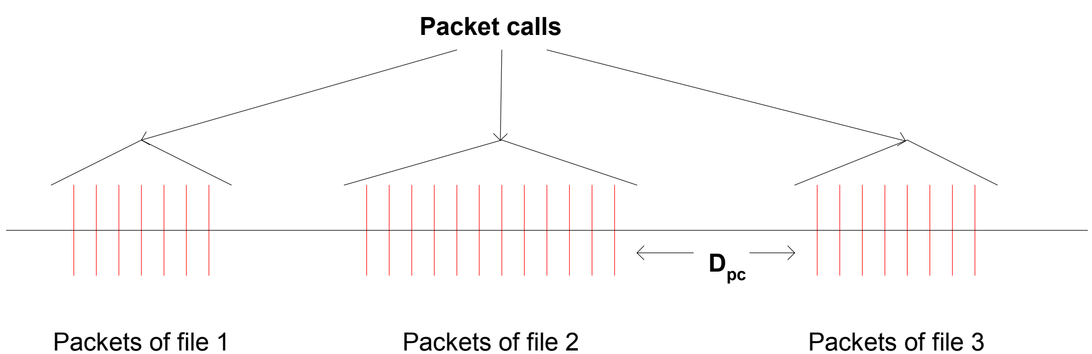
Traffic Models (cont'd)

- Data Traffic: FTP, web browsing (HTTP), WAP, near real time video.
- Different traffic models for FL and RL, e.g. web browsing
  - RL traffic: http requests
  - FL traffic: web page downloads.
- Must pay attention to interactions with TCP.
- Different assignment probability for each traffic type

HTTP	FTP	WAP	Real Time Video
24.43%	9.29%	56.43%	9.85%

FTP Traffic Model

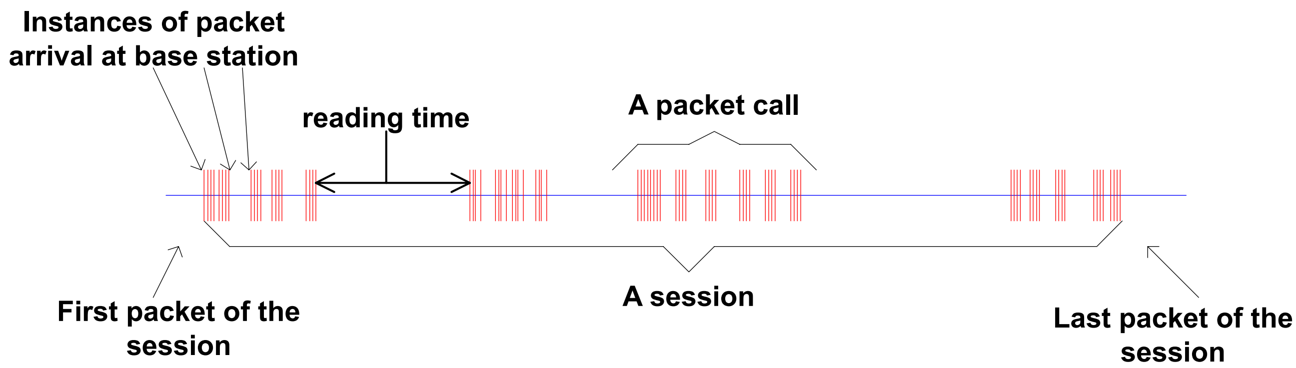
- Uses TCP as the transport protocol.
- An FTP session consists of a sequence of file transfers separated by ***reading times***. Two main parameters:
  - ***S*** : size of file to be transferred
  - $\boldsymbol{D_{pc}}$: reading time
- For each file transfer a new TCP connection is used whose initial congestion window size is MTU (segment). An MTU could be 576 bytes or 1500 bytes.
- Packet arrival process described by the TCP traffic model.



FTP Traffic Model (cont'd)

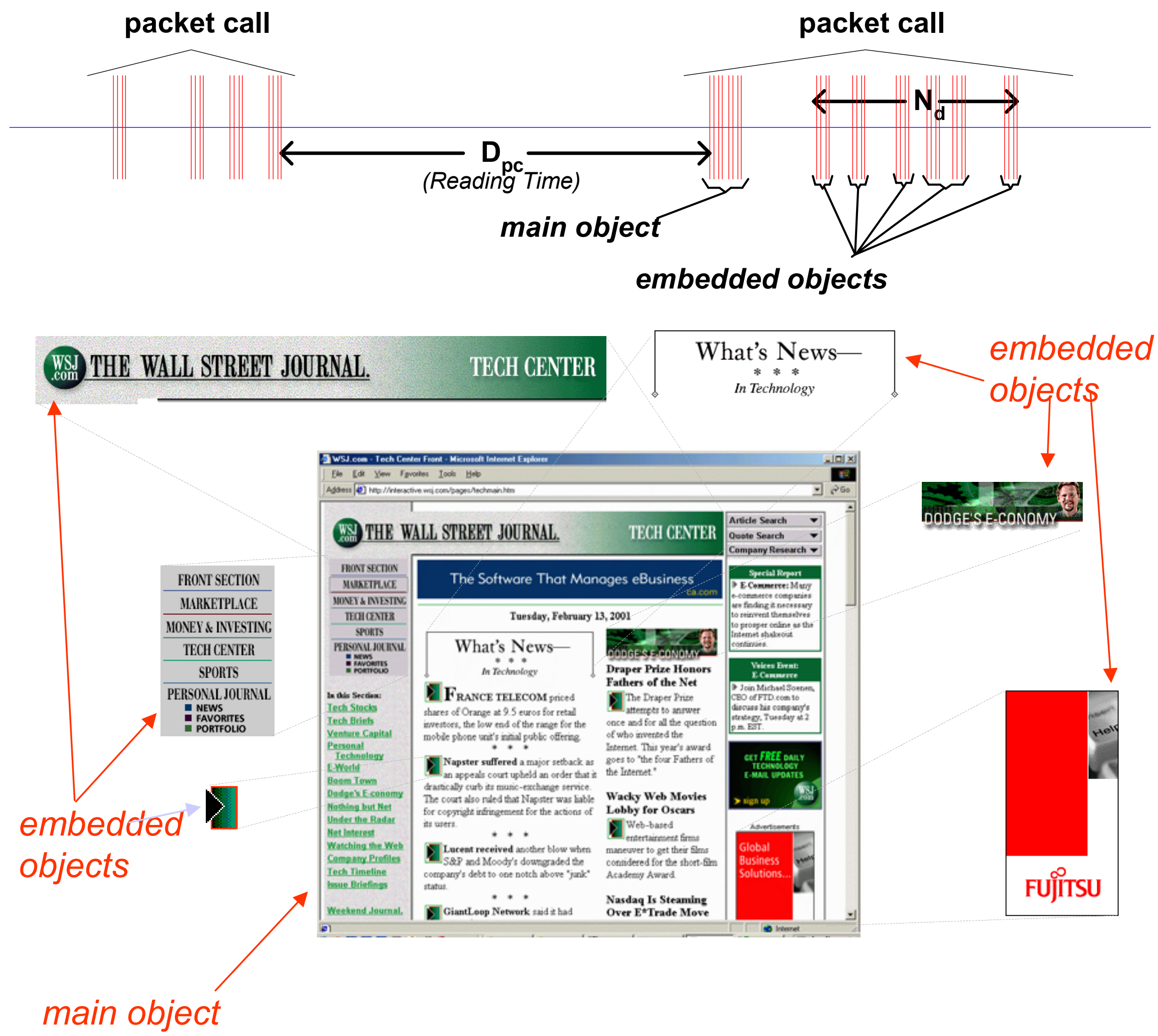
Parameter	Distribution	Parameters	PDF
File size (S)	Truncated Lognormal	Mean = 2Mbytes Std. Dev. = 0.722 Mbytes Maximum = 5 Mbytes	$f_x = \frac{1}{\sqrt{2\pi}\sigma x} \exp\left[\frac{-(\ln x - \mu)^2}{2\sigma^2}\right], x \geq 0$ $\sigma = 0.35, \mu = 14.45$
Reading time (D_{pc})	Exponential	Mean = 180 sec.	$f_x = \lambda e^{-\lambda x}, x \geq 0$ $\lambda = 0.006$

HTTP Traffic Model



- Uses TCP as its transport protocols.
- A session is made of ON/OFF periods representing web downloads and intermediate reading times.
- The traffic is self similar (the traffic exhibits similar statistics on different time scales)
- Each web download is made of a made of a main object and a number of embedded objects
- Two versions of HTTP
  - HTTP/1.0: a distinct TCP connection is used for each object. May have up to 4 parallel connections (burst mode).
  - HTTP/1.1: 1 TCP connection is used to transmit each object (persistent mode).

HTTP Traffic Model (cont'd)



HTTP Traffic Model (cont'd)

Component	Distribution	Parameters	PDF
Main object size (S_M)	Truncated Lognormal	Mean = 10710 bytes Std. dev. = 25032 bytes Minimum = 100 bytes Maximum = 2 Mbytes	$f_x = \frac{1}{\sqrt{2\pi}\sigma x}\exp\left[\frac{-(\ln x-\mu)^2}{2\sigma^2}\right], x \ge 0$ $\sigma = 1.37, \mu = 8.35$
Embedded object size (S_E)	Truncated Lognormal	Mean = 7758 bytes Std. dev. = 126168 bytes Minimum = 50 bytes Maximum = 2 Mbytes	$f_x = \frac{1}{\sqrt{2\pi}\sigma x}\exp\left[\frac{-(\ln x-\mu)^2}{2\sigma^2}\right], x \ge 0$ $\sigma = 2.36, \mu = 6.17$
Number of embedded objects per page (N_d)	Truncated Pareto	Mean = 5.64 Max. = 53	Note: Subtract k from the generated r.v. to get N_d $f_X(x) = \frac{\alpha \cdot k^\alpha}{x^{\alpha+1}},\ k \le x < m$ $\alpha = 1.1, k = 2, m = 55$
Reading time (D_{pc})	Exponential	Mean = 30 sec	$f_x = \lambda e^{-\lambda x}, x \ge 0$ $\lambda = 0.033$
Parsing time (T_p)	Exponential	Mean = 0.13 sec	$f_x = \lambda e^{-\lambda x}, x \ge 0$ $\lambda = 7.69$

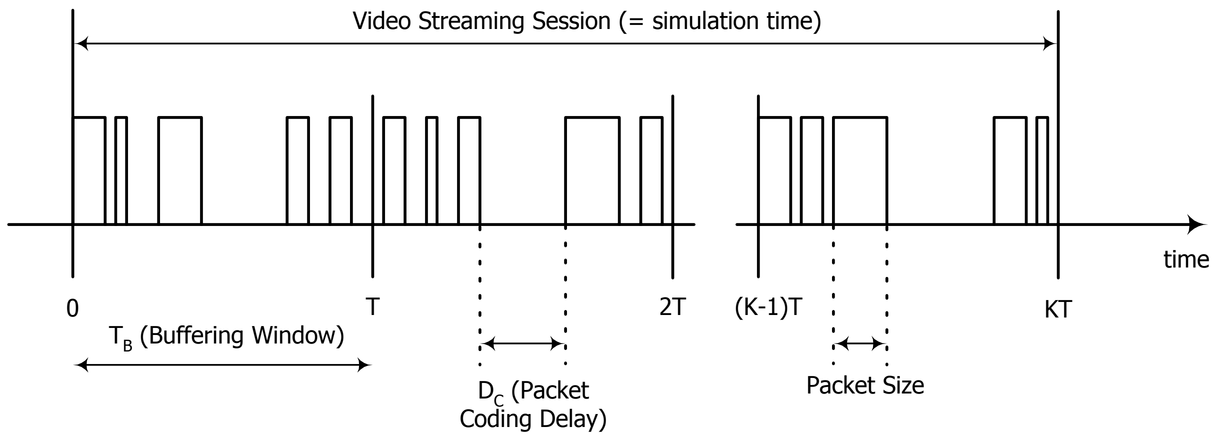
WAP Traffic Model

Packet based information types	Size of WAP request	Object size	# of objects per response	Inter-arrival time between objects	WAP gateway response time	Reading time
Distribution	**Deterministic**	**Truncated Pareto (Mean= 256 bytes, Max= 1400 bytes)**	**Geometric plus offset of 1**	**Exponential**	**Exponential**	**Exponential**
Distribution Parameters	**76 octets**	**K = 71.7 bytes, α = 1.1**	**Mean = 2 plus offset of 1**	**Mean = 1.6 s**	**Mean = 2.5 s**	**Mean = 5.5 s**

- Each WAP request will have a fixed size.
- Each WAP User is assumed to be continuously active:

Make a WAP request → Wait for a response → Wait for reading time → Make the next WAP request

Real Time Video Traffic Model



- A video streaming session is divided into a number of frames arriving at a regular interval of T sec (depends on the fps)
- Each frame is divided into a fixed number of packets or slices, each is transmitted as a single packet.
- Parameters:
  - Inter-arrival time between frames
  - Number of packets in a frame
  - Packet size
  - Inter-arrival time between packets within a frame

Real Time Video Traffic Model (cont'd)

Information Type	Inter-arrival time between frames	Number of packets (slices) in a frame	Packet (slice) size	Inter-arrival time between packets (slices) in a frame
Distribution	Deterministic (based on 10 fps)	Deterministic	Truncated Pareto Mean=50 bytes Max=125 bytes	Truncated Pareto Mean=6 ms Max=12.5 ms
Parameters	100 ms	8	K=20bytes, α=1.2	K=2.5ms, α=1.2

Traffic Model for a 32kps, 10fps video streaming session

Summary

- ***Things that we covered:***
  - Channel and fading models.
  - Data Traffic Models for FL.
- ***Things that need to be covered:***
  - C/I calculations (models?).
  - Fairness and delay criteria.
  - Performance metrics for data services.
  - Reverse Link.