1xEV-DV Evaluation Methodology

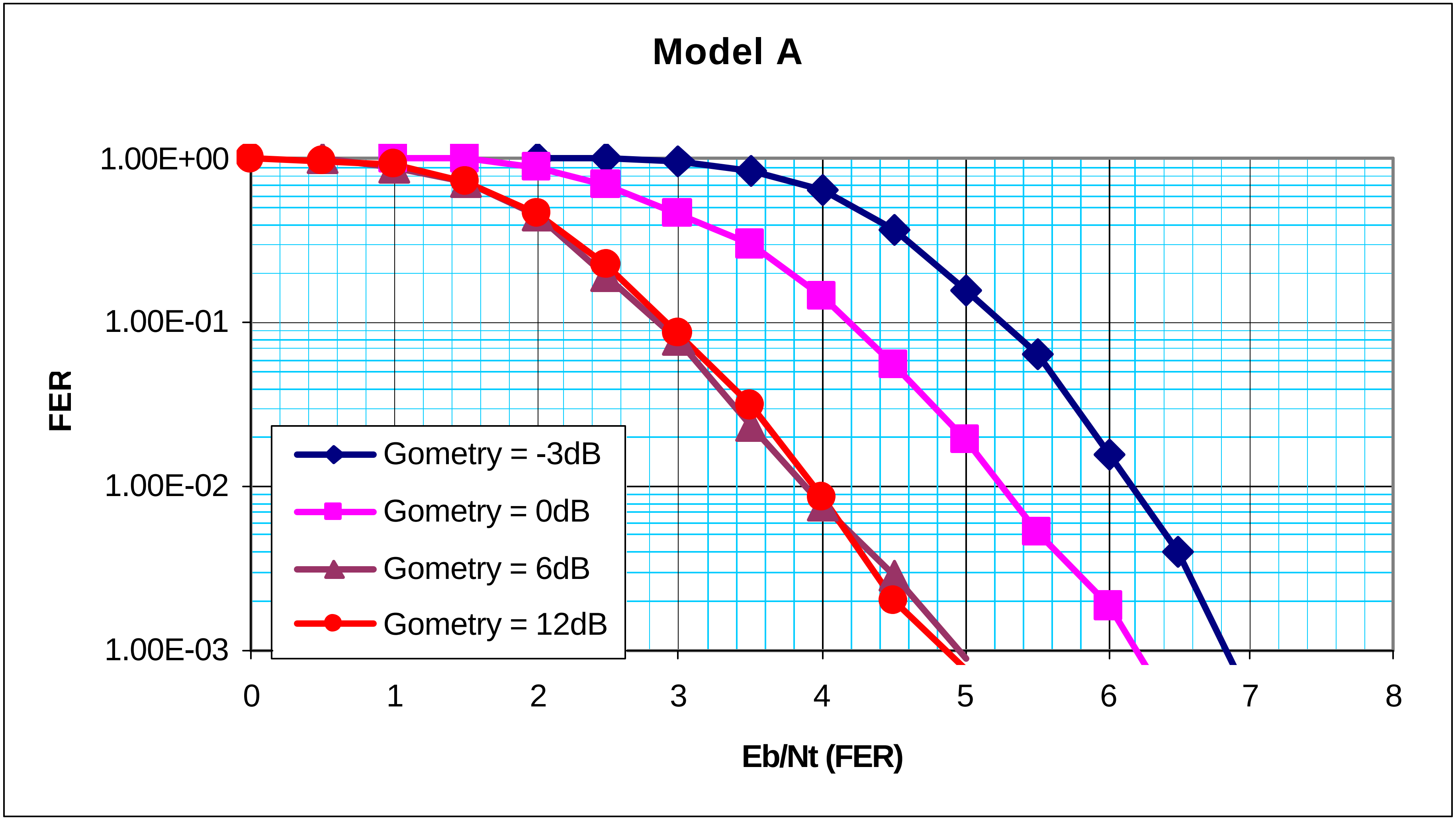
Objective and Overview

- Goal is to describe a common simulation environment for simulating 1xEV-DV systems
- Evaluations are to be simulated using the common simulation environment
- Developed 89 page “Evaluation Strawman” document
- Covers both Forward Link and Reverse Link
- Provides
  - Definitions
  - Assumptions
  - Methodology
- Primarily consists of a description of:
  - Link level simulation
  - System level simulation

Link Level Modeling

- Joint link/system level simulation too complex computationally
- Split simulations between system level and link level
- For voice, developed a set of short term FER curves where received Eb/Nt is that measured over a frame
- For the turbo encoded packet channel, used a quasi-static approach
  - The aggregated Es/Nt is computed over a transmission period and mapped to an FER using AWGN curves
  - FER is determined by:
    - » Map the aggregated Es/Nt directly to the AWGN curve corresponding to the given modulation and coding
    - » Adjust the aggregated Es/Nt for the given modulation and coding and lookup a curve obtained using a reference modulation and coding
  - Corrections used for higher velocities
- Control channels are directly modeled

Short Term Voice Curves for Traffic Model A (1 path 3 km/hr)



System Level Simulation

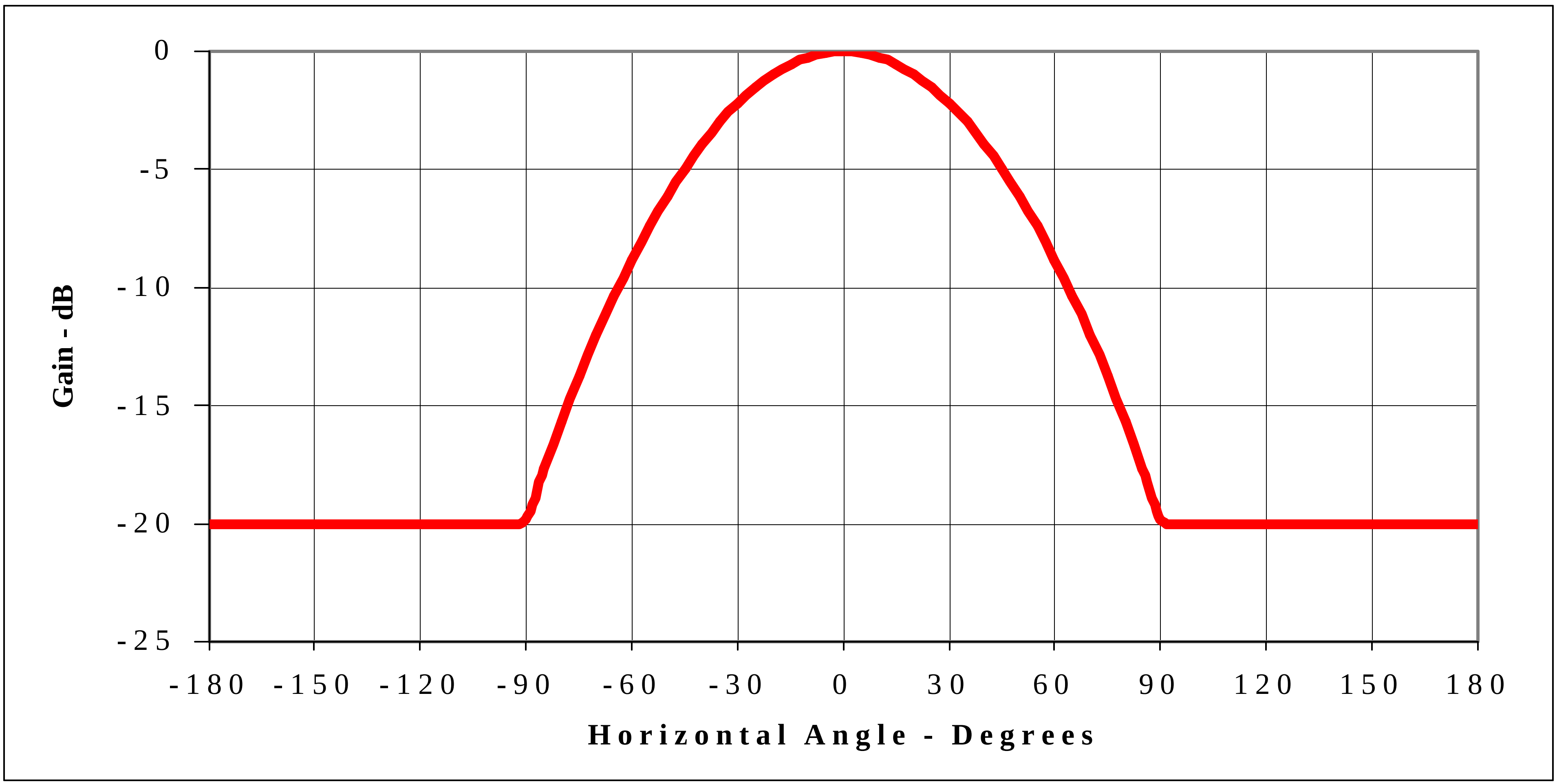
- Operates at 1.25 ms intervals (cdma2000 power control group interval)
- Independent simulations for Forward and Reverse links (coupling done through simple error models)
- Takes into account
  - Fast power control loops (800 Hz)
  - Slow power control loops
  - Scheduling
  - Protocol execution
  - C/I feedback delays
  - Acknowledgement delays
  - Different propagation models
  - Different traffic types

Some FL System Simulation Parameters

Parameter	Value	Comments
Number of Cells (3 sectored)	19	2 rings, 3-sector system, 57 sectors.
Propagation Model (BTS Ant Ht=32m, MS=1.5m)	28.6+ 35log10(d) dB, d in meters	Modified Hata Urban Prop. Model @1.9GHz (COST 231). Minimum of 35 meters separation between MS and BS.
Log-Normal Shadowing	Standard Deviation = 8.9 dB	Independently generate lognormal per mobile
Base Station Correlation	0.5	
Overhead Channel Forward Link Power Usage	Pilot, Paging and Sync overhead: 20%.	Any additional overhead needed to support other control channels (dedicated or common) must be specified and justified
Fast Fading Model	Based on Speed	Jakes or Rician
Active Set Parameters		Secondary pilots within 6 dB of the strongest pilot and above minimum Ec/Io threshold (-16dB). The active set is fixed for the drop. The maximum active set size is three.
Forward Link Power Control (If used on dedicated channel)	Power Control loop delay: two PCGs	Update Rate: Up to 800Hz PC BER: 4%

Antenna Pattern

$$A(q) = -\min\left[12\left(\frac{q}{q_{3dB}}\right)^2,\ A_m\right] \quad \text{where} \quad -180 \le q \le 180$$



Channel Models

Channel Model	Multi-path Model	# of Fingers	Speed (kmph)	Fading	Assignment Probability
Model A	Pedestrian A	1	3	Jakes	0.30
Model B	Pedestrian B	3	10	Jakes	0.30
Model C	Vehicular A	2	30	Jakes	0.20
Model D	Pedestrian A	1	120	Jakes	0.10
Model E	Single path	1	0, f_D=1.5 Hz	Rician Factor K = 10 dB	0.10

Fractional Recovered Power and Fractional Unrecovered Power

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Model	Finger1 (dB)	Delay	Finger2 (dB)	Delay (Tc)	Finger3 (dB)	Delay (Tc)	FURP (dB)
Ped-A	-0.06	0.0					-18.8606
Ped-B	-1.64	0.0	-7.8	1.23	-11.7	2.83	-10.9151
Veh-A	-0.9	0.0	-10.3	1.23			-10.2759

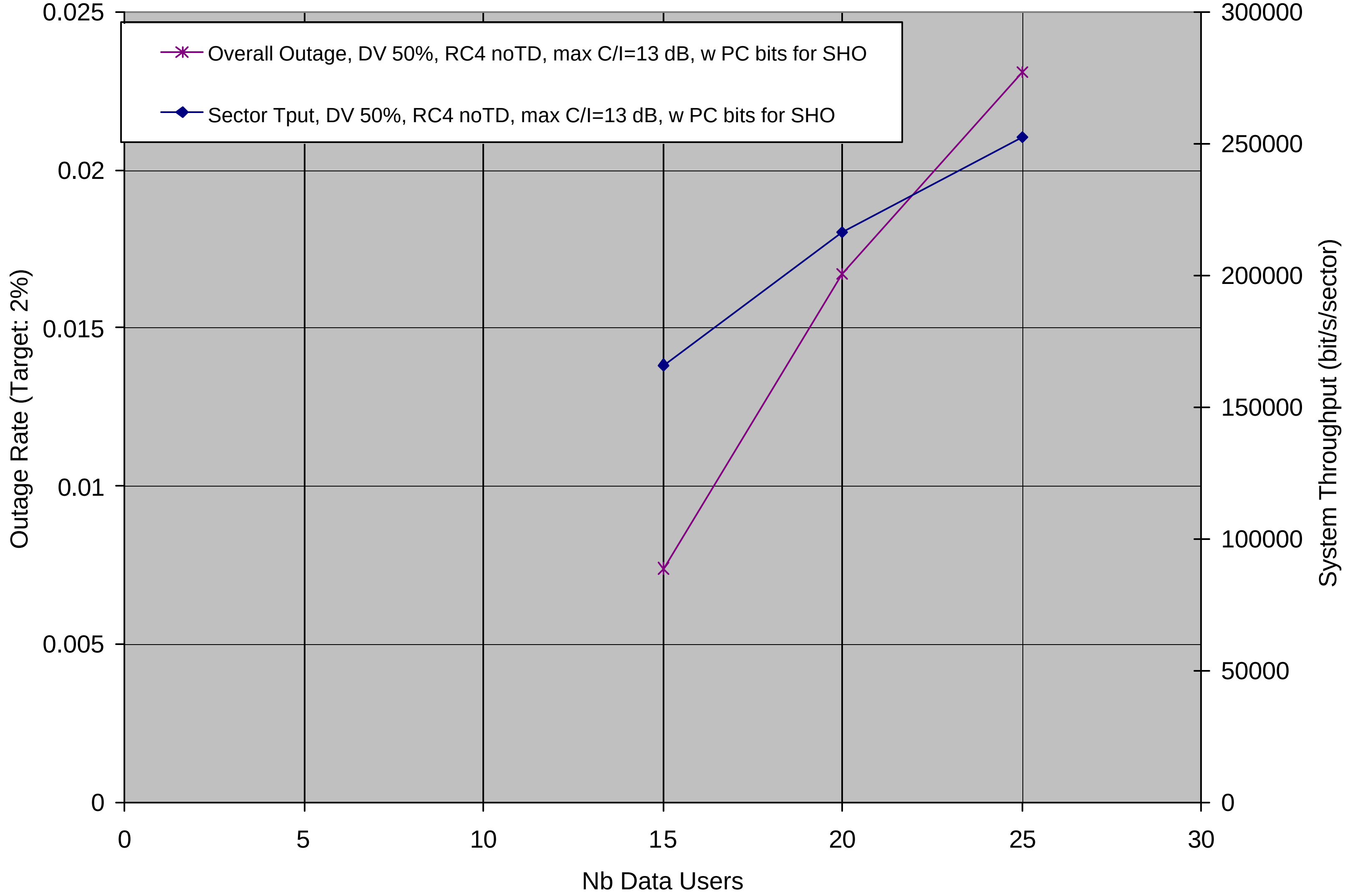
Traffic Models

- **Combination of**
  - **FTP**
  - **HTTP 1.0**
  - **HTTP 1.1**
  - **WAP**
  - **Video streaming**
  - **Voice (standard cdma2000 variable rate)**
- **Takes into account statistics of the traffic, multiple objects, TCP slow start**
- **Takes into account some aspects of TCP (e.g., slow start, 3-way handshake, TCP packet size, typical windows), but does not fully model TCP**

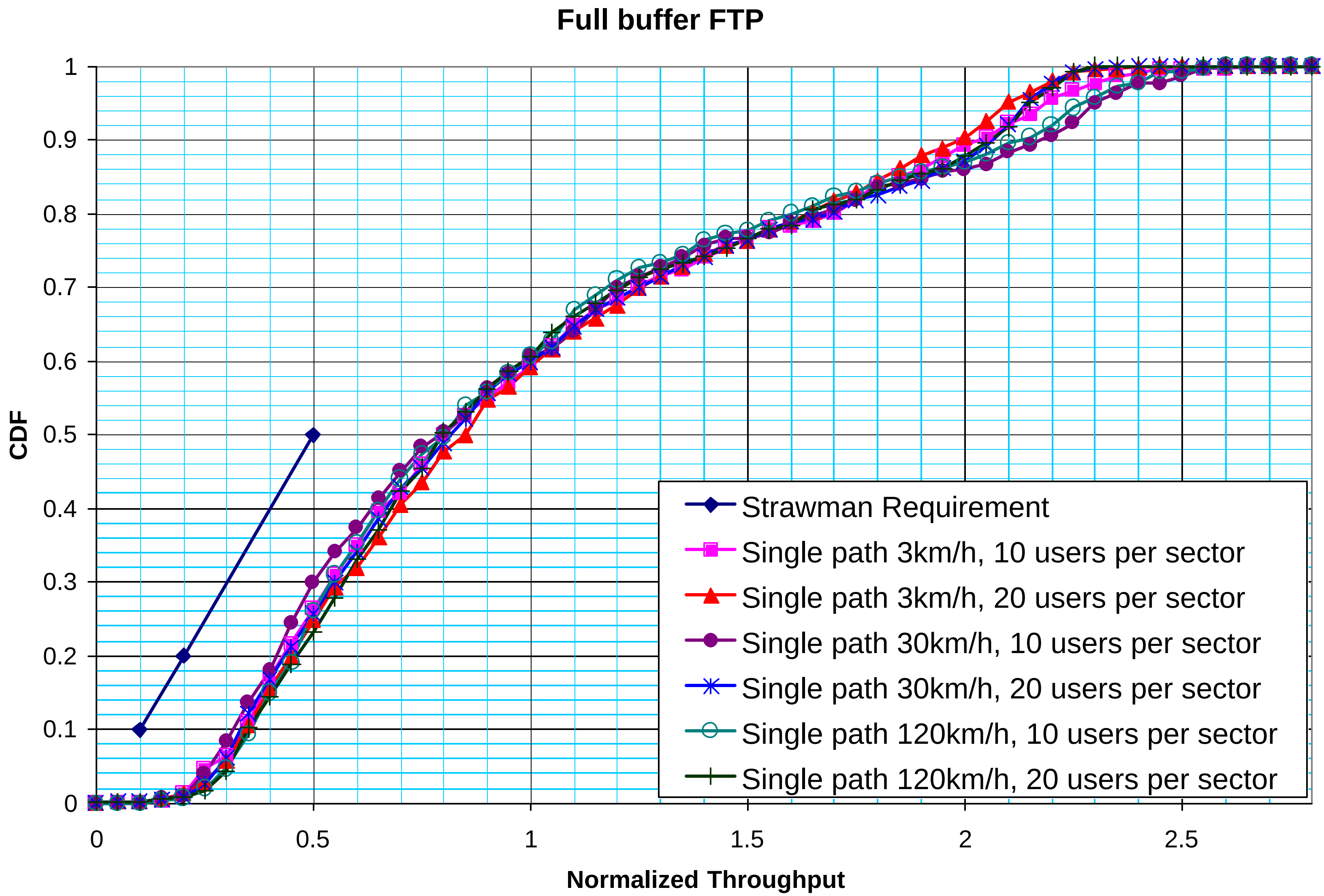
Delay / Outage Criteria

- **For HTTP or FTP users - no more than 2% of the users shall get less than 9600 bps.**
- **For WAP - no more than 2% of the users shall get less than 4800 bps.**
- **For Neal Real Time Video - no more than 2% of the users shall get less than 9600 bps AND more than 98% of the users shall meet the following performance requirement: the fraction of video frames that are not completely transmitted within 5 seconds of their arrival at the scheduler shall be less than 2% for each user**
- **Voice – must meet system outage of less than 3%**
  - **System outage is Prob(Per-user outage among all N users in all runs) < $T_{system\ outage}$ = 3%**
  - **Per-user outage is defined as the event where a user's voice connection in either direction has short-term FER higher than 15% more often than $T_{per\ link}$ = 1% of the time**
- **Also test of scheduler fairness (for FTP and HTTP traffic)**

Example of FL Outage
(50% Voice, RC3, Max C/I=13 dB)



Example of Fairness Criteria
(FTP Full Buffers)



Required 1xEV-DV Simulation Evaluation Comparison Cases

	Loading Scenarios	Tx Diversity	no Tx Diversity	Max C/I 13.0 dB	Max C/I 17.8 dB	RC3	RC4
1	voice only 100% (Nmax) load	x		x		x	
2			x	x		x	
3		x		x			x
4			x	x			x
5		x			x	x	
6			x		x	x	
7		x			x		x
8			x		x		x
9	1xEVDV data only	x		x			
10			x	x			
11		x			x		
12			x		x		
13	50%voice + 1xEVDV data	x		x		x	
14			x	x		x	
15		x		x			x
16			x	x			x
17		x			x	x	
18			x		x	x	
19		x			x		x
20			x		x		x
21	80%voice + 1xEVDV data	x		x		x	
22			x	x		x	
23		x		x			x
24			x	x			x
25		x			x	x	
26			x		x	x	
27		x			x		x
28			x		x		x

Some Output Matrices

1. Data throughput per sector
2. Averaged packet delay per sector
3. The histogram of data throughput per user
4. The histogram of packet call throughput for users with packet call arrival process. The histogram of averaged packet delay per user
5. The histogram of averaged packet call delay for users with packet call arrival process
6. The scattering plot of data throughput per user vs. the distance from the user's location to its serving sector
7. The scattering plot of packet call throughputs for users with packet call arrival processes vs. the distance from the users' locations to their serving sectors
8. The scattering plot of averaged packet delay per user vs. the distance from the mobile's location to its serving sector
9. The scattering plot of averaged packet call delays for users with packet call arrival processes vs. the distance from the mobiles' locations to their serving sectors
10. The scattering plot of data throughput per user vs. its averaged packet delay
11. The scattering plot of packet call throughputs for users with packet call arrival processes vs. their averaged packet call delays
12. The scattering plot of packet call throughputs for users with packet call arrival processes vs. their averaged packet call delays

Example FL Outage Prob versus Distance
(Voice only, RC3, Max C/I=13 dB)

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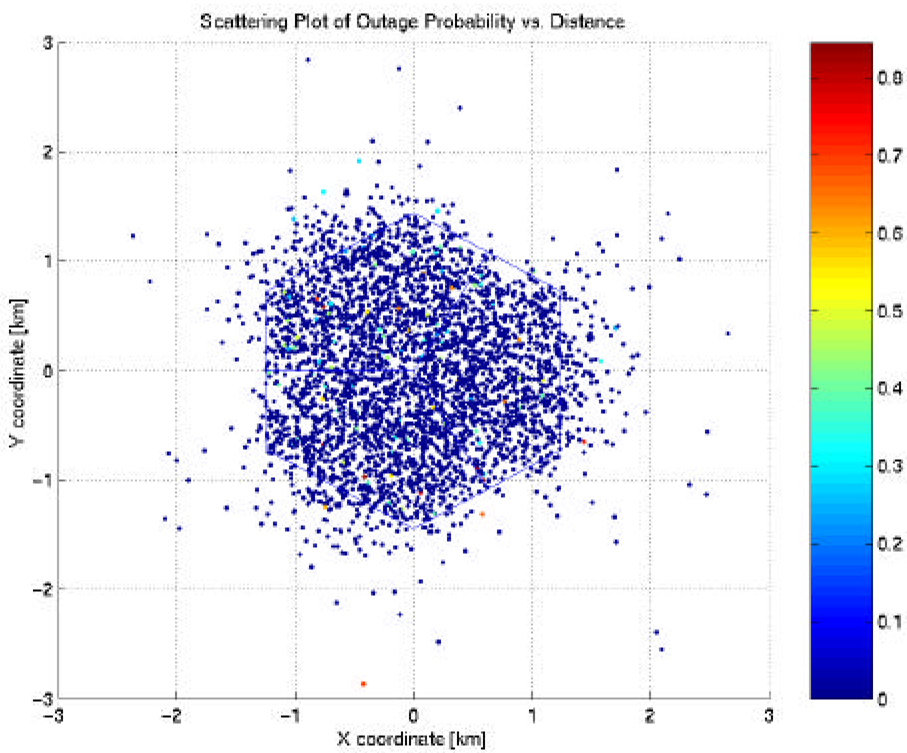
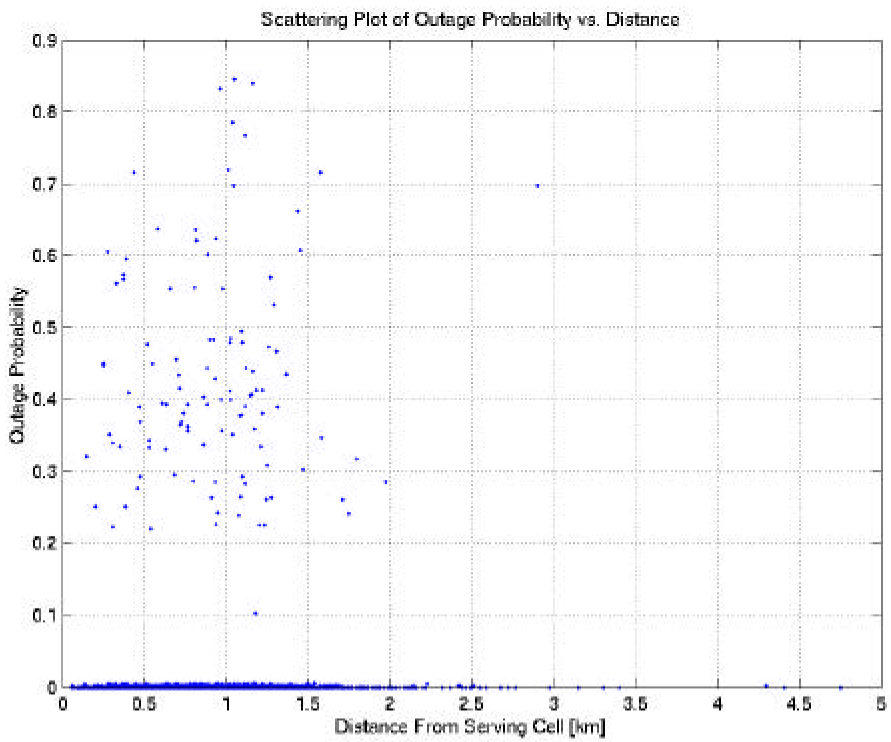
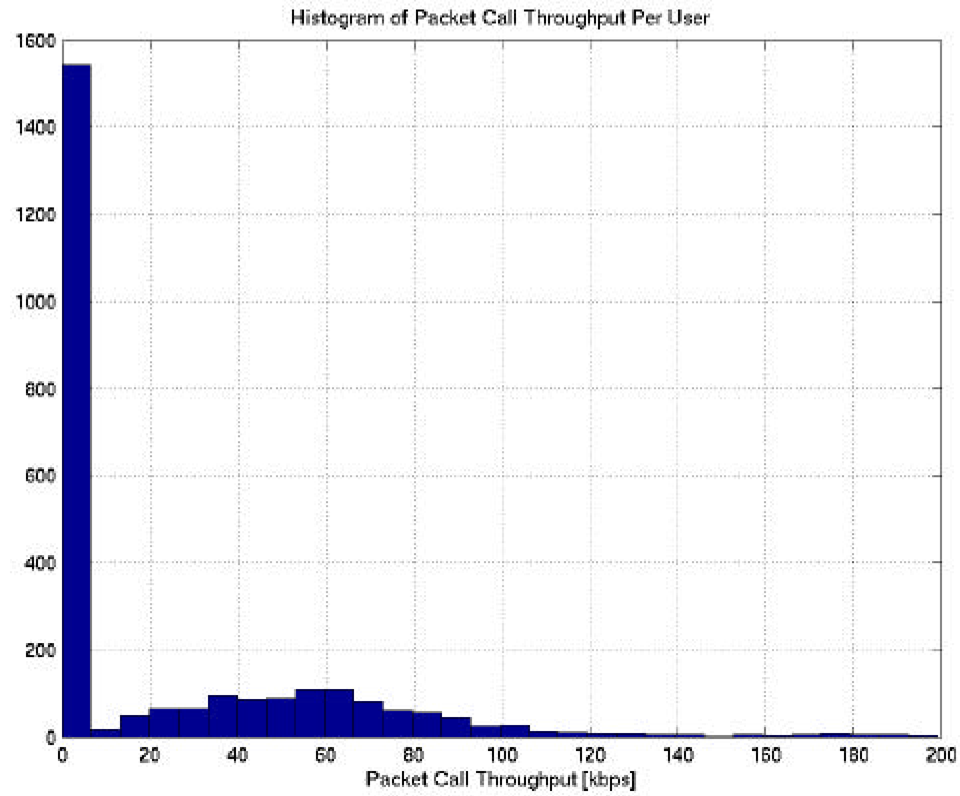
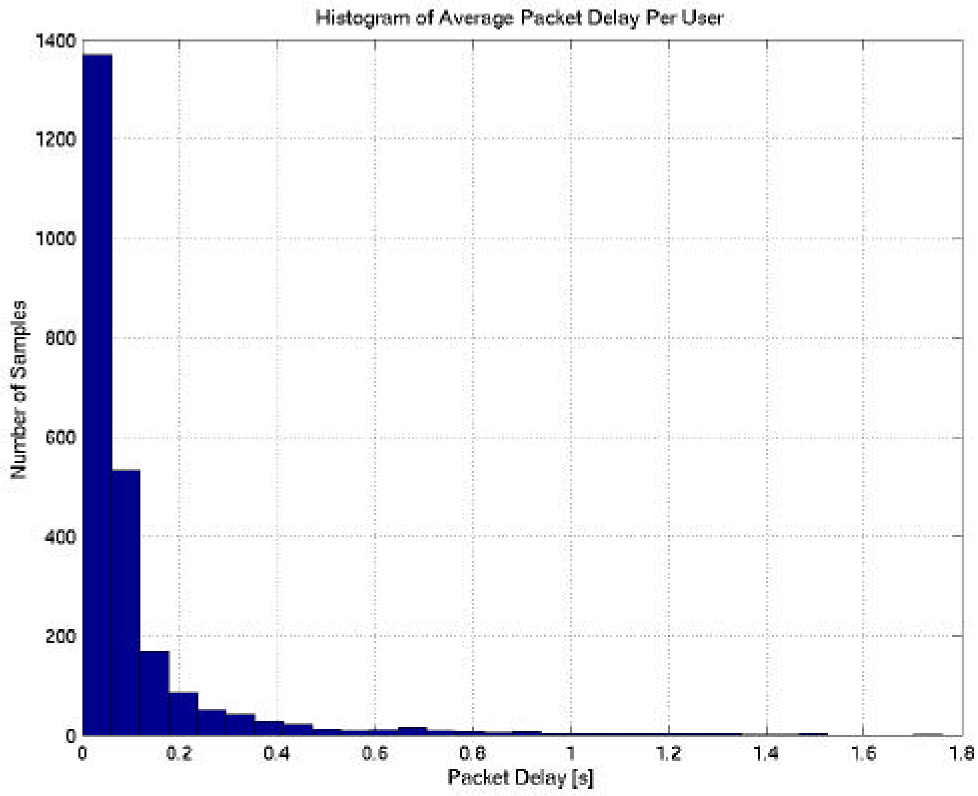
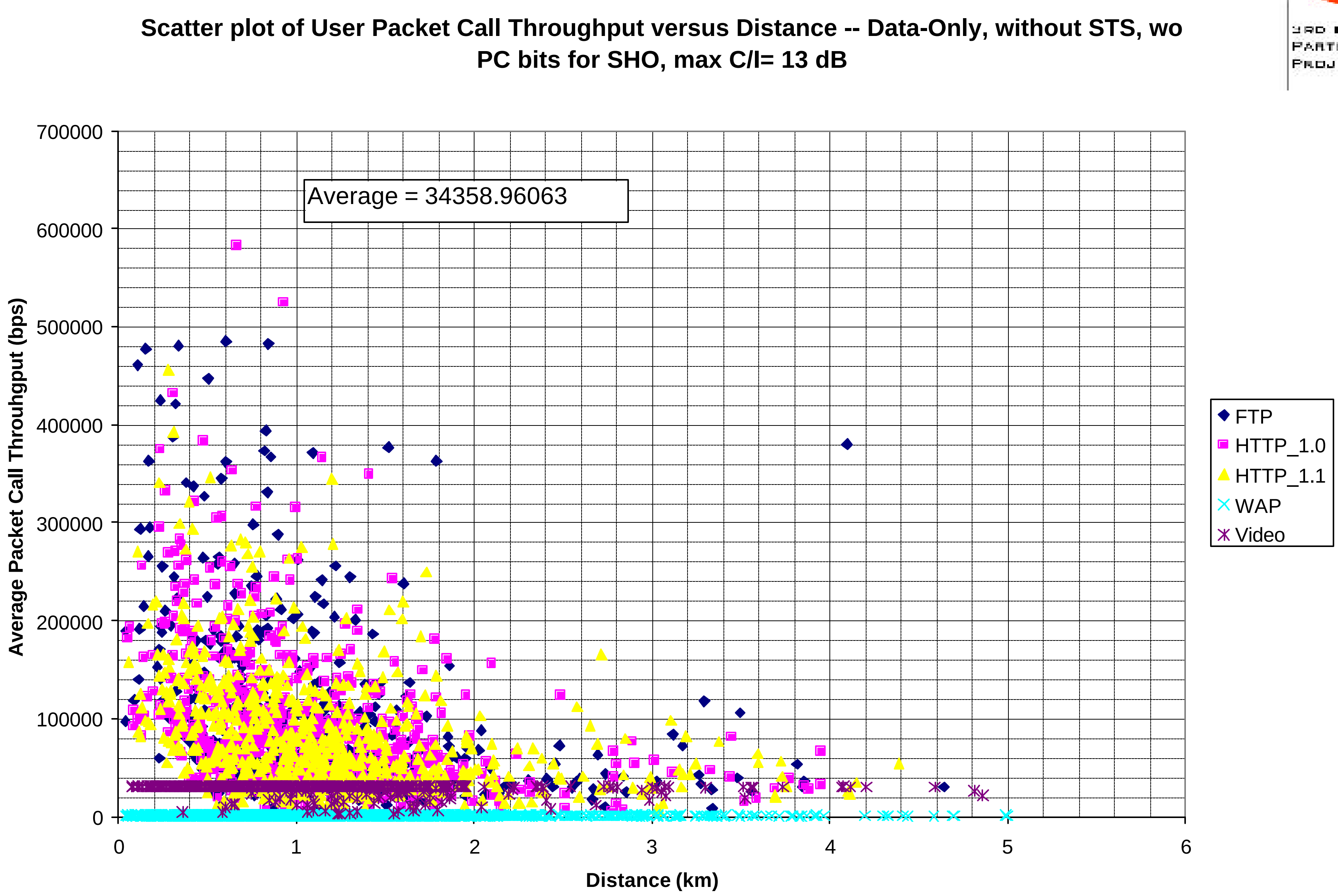




Example FL Average Packet Call Throughput and Delay
(Data only, Max C/I=13 dB)






Scatter plot of User Packet Call Throughput versus Distance -- Data-Only, without STS, wo PC bits for SHO, max C/I= 13 dB
Average = 34358.96063
Average Packet Call Throuhgput (bps)
700000
600000
500000
400000
300000
200000
100000
0
0
1
2
3
4
5
6
Distance (km)
FTP
HTTP_1.0
HTTP_1.1
WAP
Video

Additional Viewgraphs on 1xEV-DV Evaluation Methodology

C/I Computation with Pilot Weighted Combining

$$(C/I)_i = \frac{\|g_i\|^2}{G^{-1} + \|l\|^2 + \sum_{1 \le k \le J, k \ne i} \|g_k\|^2}$$

$$G = \frac{\hat{I}_{or}}{N_0 + \sum_{n=1}^{N} I_{oc}(n) \|r_n\|^2}$$

$$(C/I)_{\text{combined}} = \frac{\left(\sum_{i=1}^{J} \|g_i\|^2 \right)^2}{\sum_{j=1}^{J} \|g_j\|^2 \left(G^{-1} + \|l\|^2 + \sum_{1 \le k \le J, k \ne j} \|g_k\|^2 \right)}$$

$\{g_i\}_{i=1}^{J}$ denote the samples of the fading processes, for a particular PCG, of the J recovered rays; l denote the sample of the fading process for the additional ray used to model interference due to the unrecovered power, for a particular PCG

N is the number of interfering sectors, r_n is the fading process of the ray between the receiver and the n-th interfering sector for a particular PCG, N_0 is the variance of the thermal noise

Effective C/I with Max C/I Cap

$$a = \frac{1}{(C/I)_{\text{max}}}$$

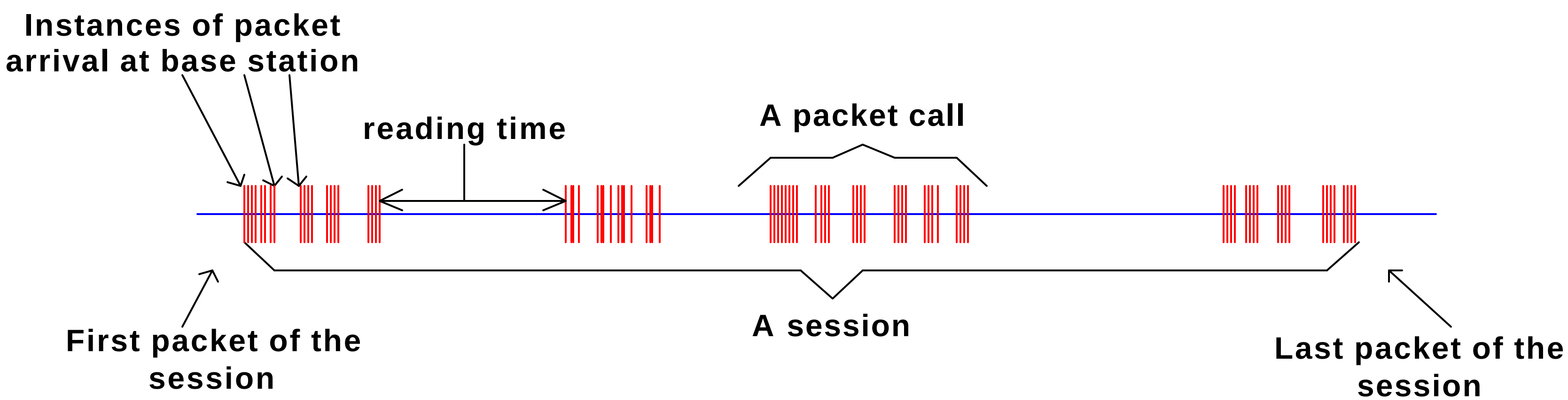
$$(C/I)_{\text{effective}} = \frac{1}{\frac{1}{(C/I)_{\text{combined}}} + a}$$

The maximum C/I achievable in the subscriber receiver is limited by inter-chip interference induced by the base-band pulse shaping waveform, the radio noise floor, ADC quantization error, and adjacent carrier interference.

Mix of Service

- A configurable fixed number of voice calls are maintained during each simulation run. Data sector throughput is evaluated as a function of the number of voice users supported.
- Four cases studied: no voice users (i.e., data only), voice users only (i.e., the number of voice users equals to voice capacity), and average ë$0.5N_{max}$û or ë$0.8N_{max}$û voice users per sector plus data users, where N_{max} is the voice capacity.
- The data users in each sector are assigned one of the four traffic models: WAP (56.43%), HTTP (24.43%), FTP (9.29%), near real time video (9.85%), with the respective probabilities in parentheses.

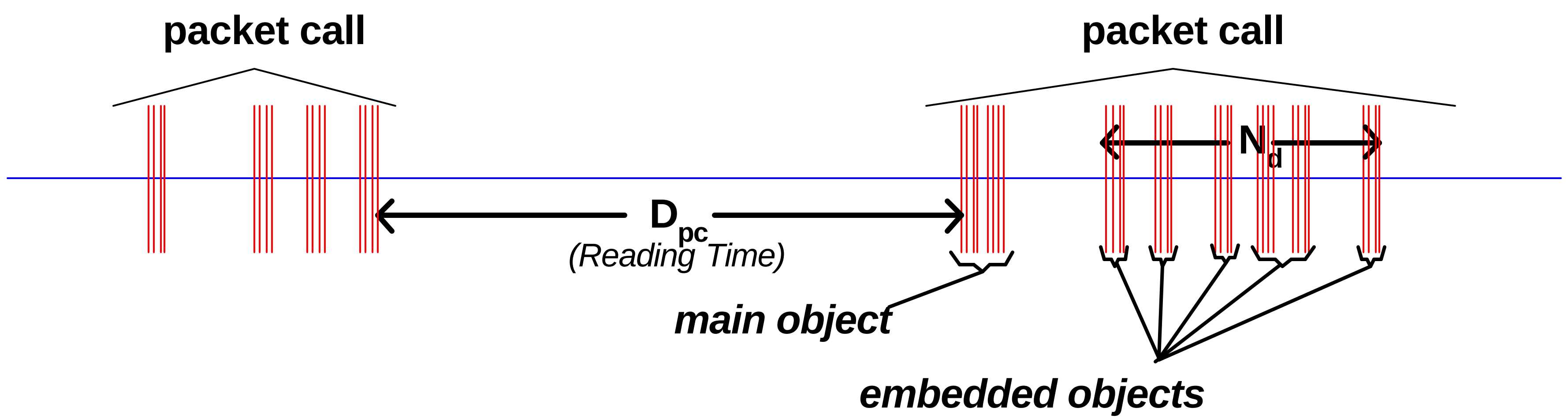
HTTP Traffic Model



Packet Trace of a Typical Web Browsing Session

A Typical Web Page and Its Contents

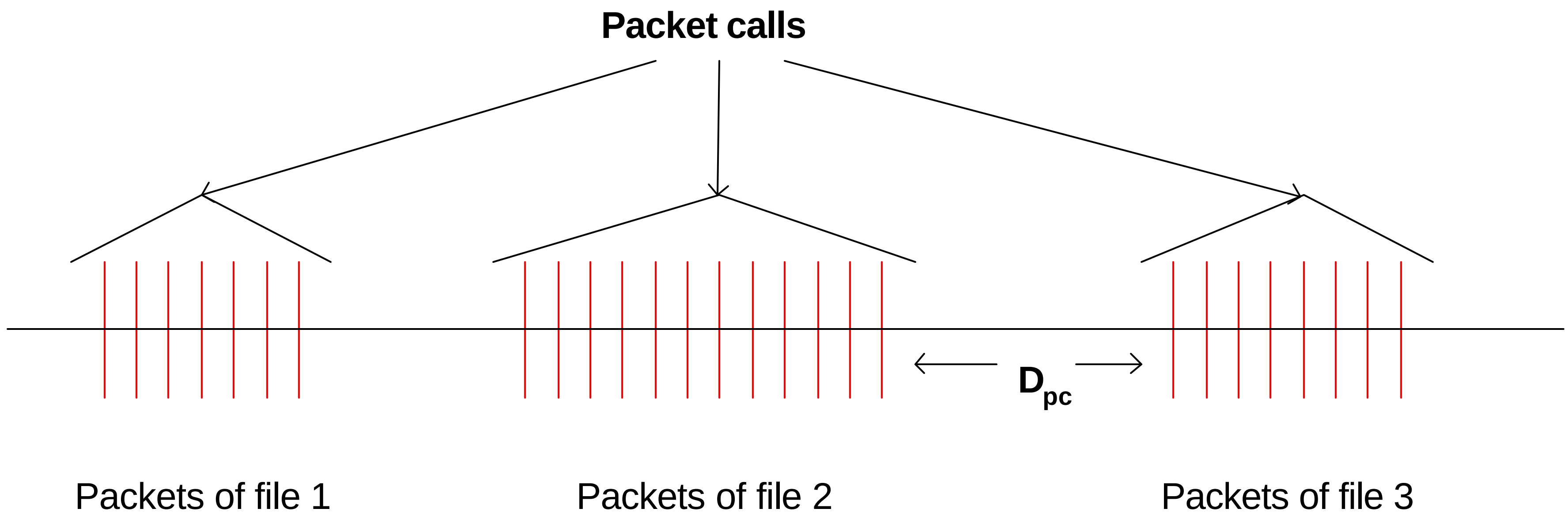
Contents in a Packet Call



HTTP Traffic Model Parameters

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

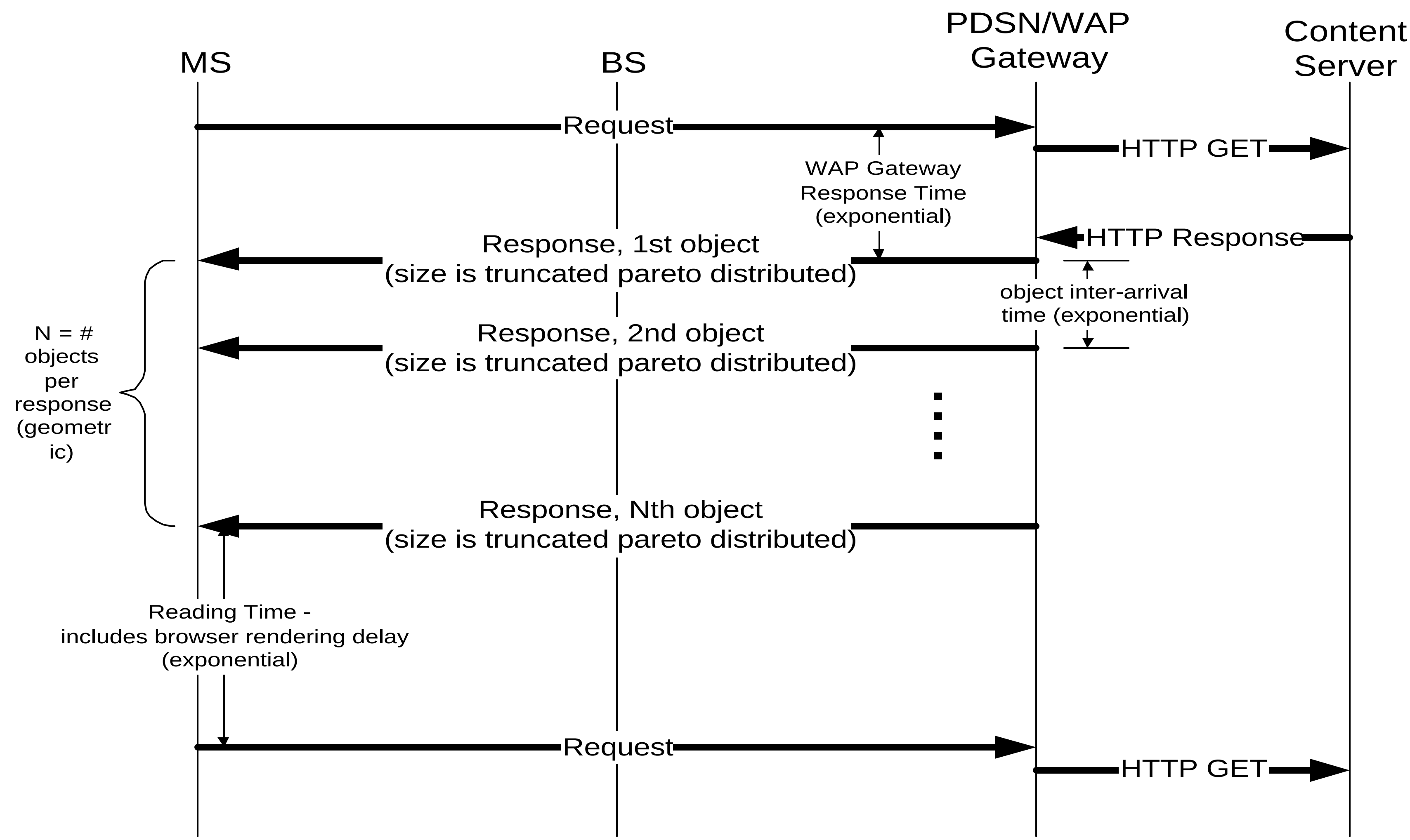
FTP Traffic Model



FTP Traffic Model Parameters

Component	**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.	$f_x = \lambda e^{-\lambda x}, x \geq 0$ $\lambda = 0.006$

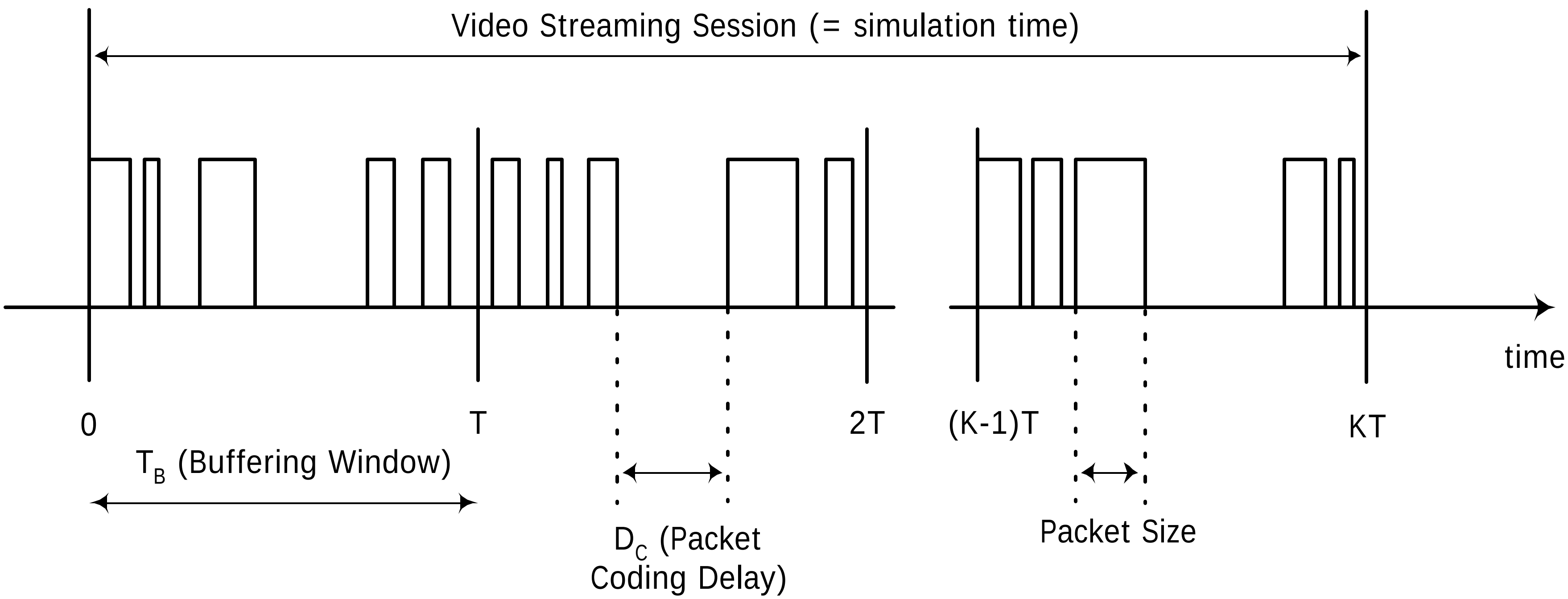
WAP Traffic Model



WAP Traffic Model Parameters

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	Exponential	Exponential	Exponential
Distribution Parameters	76 octets	K = 71.7 bytes, $\alpha = 1.1$	Mean = 2	Mean = 1.6 s	Mean = 2.5 s	Mean = 5.5 s

Near Real Time Video Traffic Model



Neal Real Time Traffic Model Parameters

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

Fairness Criteria

- Because maximum system capacity may be obtained by providing low throughput to some users, it is important that all mobile stations be provided with a minimal level of throughput. This is called fairness.
- The fairness is evaluated by determining the normalized cumulative distribution function (CDF) of the user throughput, which meets a predetermined function in two tests (seven test conditions).
- The CDF of the normalized throughputs with respect to the average user throughput for all users shall lie to the right of the diagonal curve (y=x).
- The same scheduling algorithm is used for all simulation runs, I.e., the scheduling algorithm is not optimized for runs with different traffic mixes.

Delay / Outage Criteria

- **For HTTP or FTP users - no more than 2% of the users shall get less than 9600 bps.**
- **For WAP - no more than 2% of the users shall get less than 4800 bps.**
- **For Neal Real Time Video - no more than 2% of the users shall get less than 9600 bps AND more than 98% of the users shall meet the following performance requirement: the fraction of video frames that are not completely transmitted within 5 seconds of their arrival at the scheduler shall be less than 2% for each user**

Link Level Modeling

- Since a combined system and link simulation is a tremendous task, the performance characteristics of individual links used in the system simulation are generated a priori from link level simulations, I.e., encoding and decoding are not modeled in the system simulation.
- These link level curves are used to generate frame erasures in the system simulation.
- MAX-LOG-MAP is used as turbo decoder metric.
- Quasi-static approach with fudge factors is used to generate the frame erasures for 1xEV-DV packet data channel, dynamically simulated forward link overhead channels.
- Quasi-static approach with short term FER is used to generate the frame erasures for voice and SCH users.

Quasi-static Approach with Fudge Factors

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The aggregate Es/Nt

$$\Sigma_{E_s/N_t} = 10\log_{10}\left(\frac{1}{N}\left[\sum_{j=1}^{n} N_j \cdot (E_s/N_t)_j\right]\right),$$

where

1. N equals the number of information bits (i.e., the encoder packet size).
2. N_j equals the number of modulation symbols transmitted in slot j.
3. n is the number of slots over which the transmission occurs. This includes both the original transmission, and retransmissions, if any.
4. $(E_s/N_t)_j,\ j = 1,\ldots,n,$ is the SNR per modulation symbol for slot j. These terms are *not* in dB.
5. $(E_s/N_t)_j,\ j = 1,\ldots,n,$ is the Es/Nt observed *after* Rayleigh (or Jakes) fading.

Quasi-static Approach with Fudge Factors (II)

- **The aggregated Es/Nt is computed over a transmission period and mapped to an FER using AWGN curves.**
- **FER is determined by:**
  - **Map the aggregated Es/Nt directly to the AWGN curve corresponding to the given modulation and coding.**
  - **Adjust the aggregated Es/Nt for the given modulation and coding and lookup a curve obtained using a reference modulation and coding.**
- **Additional Es/Nt loss at higher Dopplers needs to be accounted for.**

Quasi-static Approach with Short Term FER

The short term FER vs. average Eb/Nt per frame curves are generated as follows:

1. The link-level simulation is conducted for a specific condition. The average Eb/Nt in a frame and the frame erasure indicator for the frame are recorded. The average Eb/Nt per frame is computed as follows in the link-level simulation

$$\frac{E_b}{N_t} = \frac{1}{16}\sum_{n=1}^{16}\left(\frac{m\sum_k \left(S_b^{(n,k)}\right)^2}{\sum_k \left(n_t^{(n,k)}\right)^2}\right)$$

   where n is the index of PCG in a frame and k is the index of symbols within a PCG. $S_b^{(n,k)}$ is the signal component in the k-th received coded symbol in the n-th PCG, $n_t^{(n,k)}$ is the noise and interference component in the k-th received symbol in the n-th PCG in a frame, and m is the inverse of the code rate.

2. Generate the histogram of FER vs. the average Eb/Nt per frame, i.e., the range of Eb/Nt is divided into many bins, and the FER in each bin is computed based on the outputs mentioned in step 1.

Quasi-static Approach with Short Term FER (II)

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In the system-level simulation, the average Eb/Nt per frame is computed as follows. First, the average Eb/Nt is calculated in a PCG. The short-term average Eb/Nt per frame is defined as the average of the average Eb/Nt for all 16 PCG's in a frame, i.e.,

$$\frac{E_b}{N_t} = \frac{1}{16}\sum_{n=1}^{16}\left(\frac{E_b}{N_t}\right)_n$$

where $(Eb/Nt)_n$ is the average Eb/Nt in the n-th PCG in a frame. Note. Once the Eb/Nt is calculated as in the above equation, it is used to look up the corresponding link level short term FER vs. average Eb/Nt per frame curves for the specific condition (i.e., radio configuration, transmission diversity scheme, channel model, way of soft hand-off (SHO), SHO imbalance(s), and geometry). A frame erasure event is then generated based on the FER value.

System Layout

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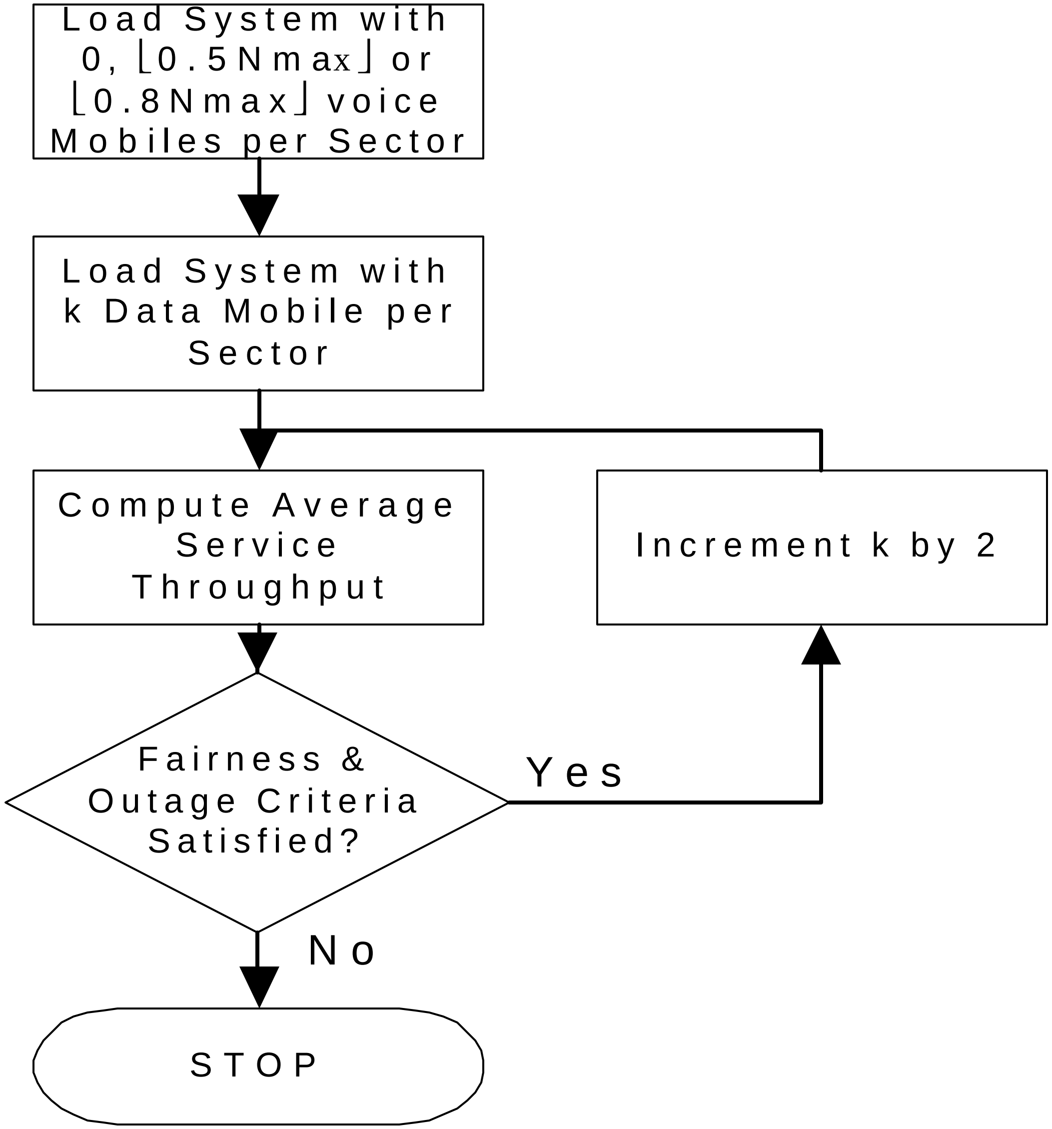
- **Center Cell Method**
  - **Mobiles are dropped over the 19 cells and dynamically simulated**
  - **Statistics are collected from the center cell only**
- **Iteration Method**
  - **Iteration 0: Passive (neighbor) cells radiate at maximum power. Power statistics of the active (central) cell is collected for use in the next iteration**
  - **Iteration n (n>0): Run the system forcing passive cells to follow the active's cell power profile found on the iteration (n-1). Time offsets are introduced to break the correlation**
  - **Only mobiles in the center cell are dynamically simulated**

Simulation Flow



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3		X		X			X
4			X	X			X
5		X			X	X	
6			X		X	X	
7		X			X		X
8			X		X		X
9	1xEVDV data only	X		X			
10			X	X			
11		X			X		
12			X		X		
13	50%voice + 1xEVDV data	X		X		X	
14			X	X		X	
15		X		X			X
16			X	X			X
17		X			X	X	
18			X		X	X	
19		X			X		X
20			X		X		X
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