WiMAX
System Level Modeling

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These slides are also available on-line at
http://www.cse.wustl.edu/~jain/wimax/gc07.htm

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- Goals of this presentation
- Link-Level vs. System-Level Simulation
- System Modeling Parameters
- Application Traffic Models
- MAC Layer Modeling
- PHY Modeling
- NS2 Model

Overview

- Goal: To provide an overview of the system level performance modeling effort at WiMAX Forum
- The methodology and the model presented here will be made available publicly by WiMAX Forum
- This work is a part of Application Working Group (AWG) at WiMAX Forum
- The modeling effort consists of two related efforts:
  - System Level Modeling Methodology Document
  - NS2 based system level model

System-Level Simulation Methodology

- Agreed upon by WiMAX Forum member experts
- Can be used by anyone to develop their own simulation
- Can be used with any modeling platform: NS-2, OPNET, …
- Specifies parameter values: ranges and default
- Specifies features and methods
- Allows comparison of performance results from different vendors
- Used in the WiMAX Forum's NS-2 Model
- Similar documents exist for 3GPP/3GPP2

Why System Level Model?

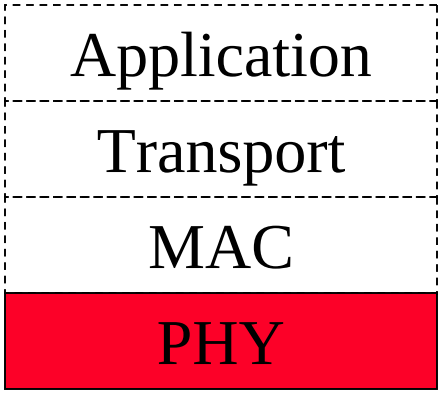
- Carriers need:
  - Capacity Planning
  - Performance Optimization
  - Operational Guidelines
- Users need:
  - Operational Guidelines
- Vendors need:
  - Performance impact of various features on applications

$\Rightarrow$ Develop a system level simulation methodology and simulation package for application performance analysis

Link-Level vs. System-Level Models

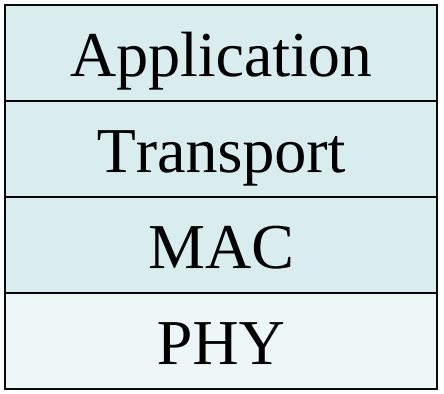
Link-Level:

- Goal: Study different signal transmission and reception schemes
- Single Link
- Single Cell
- Single Base Station
- Emphasis on PHY
- Some MAC

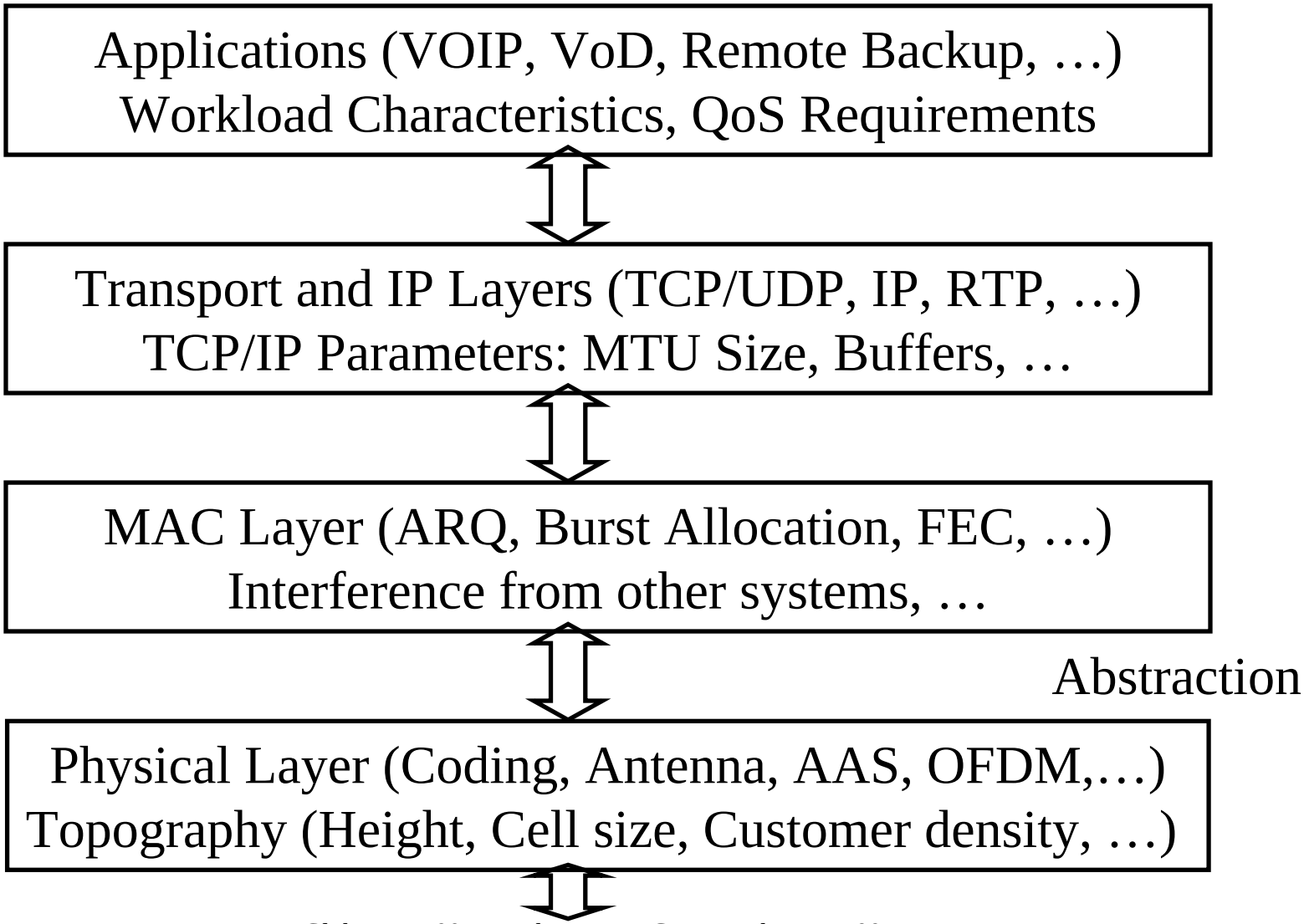


System-Level:

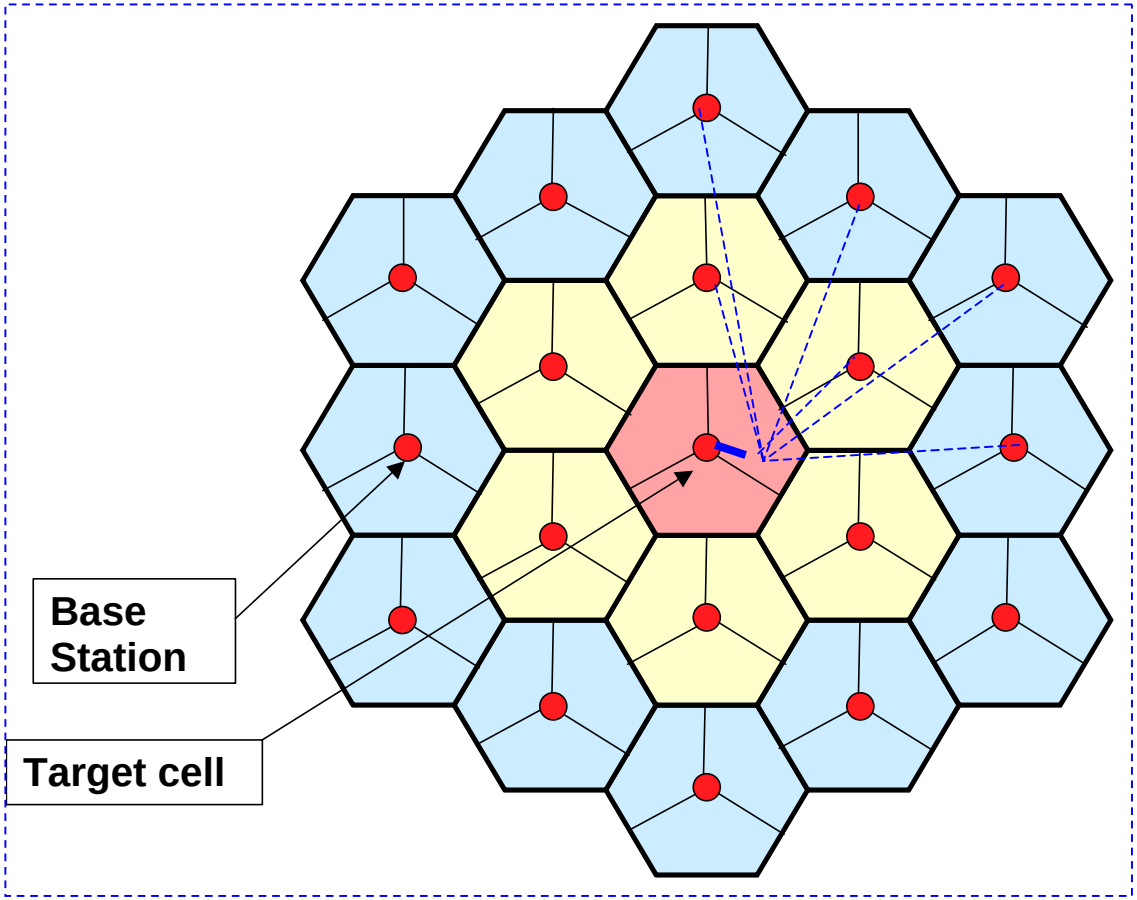
- Goal: Application level performance
- Multiple users
- Multiple cells
- Multiple Base Stations
- Emphasis on all layers
  => PHY abstracted



System-Level Model Components



Topology for System Simulation



- Distribute user session randomly among the cells
- Neighboring cell traffic to create interference in the center cell

Key Components of System Level Model

Methodology document provides details of:

- **System Definition**: Topography, Cell size, Height, Cell size, Customer density, …
- **Applications**: VOIP, VoD, Workload Characteristics, QoS Requirements
- **MAC Layer Fetaures**: ARQ, Burst Allocation, Scheduling
- **PHY Model**: Channel models, MIMO, …, PHY abstraction

System Definition Parameters

1. Network Configuration Parameters
2. Base Station Equipment Model Parameters
3. Subscriber Station Equipment Model Parameters
4. OFDMA Air Interface Parameters
5. Propagation Model Parameters
6. Methodology Parameters
7. Dynamic System Simulation Features
8. Fading and Mobility Channel Model
9. Parameters for system outage calculation

Key Contribution: These parameter values have been accepted as valid ranges and defaults by our PHY experts.

Sample: Network Configuration Params

Parameter	Description	Value Range
N_c	Number of cells.	**19**
S	Number of sectors/cell.	1, **3**, 4, 6
$N_s = SN_c$	Total number of sectors.	19, **57**, 76, 114
R	BS-to-BS distance	0.5 to 30 km **(1 km)**
ϕ_{BS}	Orientation (boresight angle) of each sector as defined by 3GPP-3GPP2 [10]	$S = 3$: $\phi_{BS} = 30, 150, 270$ $S = 6$: $\phi_{BS} = 0, 60, 120, \ldots 300$
K	Number of frequency allocations in the network.	**1**, 2, 3, 4, 6
F_{BS}	Frequency allocation (integer index) used in each BS sector.	**1**, 2, 3, 4, 5, 6
	Operating Frequency	2.0–3.5 GHz (**2.5 GHz**)
	Duplexing Scheme	**TDD**

Applications

3.1 INTERNET GAME TRAFFIC MODEL (CLASS 1)
3.2 VOIP TRAFFIC MODEL (CLASS 2)
3.2 VIDEO CONFERENCE TRAFFIC MODEL (CLASS 2)
3.3 PTT TRAFFIC MODEL (CLASS 2)
3.4 MUSIC/SPEECH TRAFFIC MODEL (CLASS 3)
3.5 VIDEO CLIP TRAFFIC MODEL (CLASS 3)
3.6 MOVIE STREAMING TRAFFIC MODEL (CLASS 3)
3.7 MBS TRAFFIC MODEL (CLASS 3)
3.8 IM TRAFFIC MODEL (CLASS 4)
3.9 WEB BROWSING (HTTP) TRAFFIC MODEL
3.10 EMAIL TRAFFIC MODEL (CLASS 4)
3.11 TELEMETRY TRAFFIC MODEL (CLASS 5)
3.12 FTP TRAFFIC MODEL (CLASS 5)
3.13 P2P TRAFFIC MODEL (CLASS 5)
3.14 VPN SERVICE
3.15 NRTV (NEAR REAL TIME VIDEO) TRAFFIC MODEL [3GPP]

Key Contribution: Many of these models are AATG original and are now part of 802.16m

Application Classes

Class	Application	Bandwidth Guideline		Latency Guideline		Jitter Guideline	
1	Multiplayer Interactive Gaming	Low	50 kbps	Low	< 25 msec	N/A	
2	VoIP & Video Conference	Low	32-64 kbps	Low	< 160 msec	Low	<50 msec
3	Streaming Media	Low to High	5 kbps to 2 Mbps	N/A		Low	<100 msec
4	Web Browsing & Instant Messaging	Moderate	10 kbps to 2 Mbps	N/A		N/A	
5	Media Content Downloads	High	> 2 Mbps	N/A		N/A	

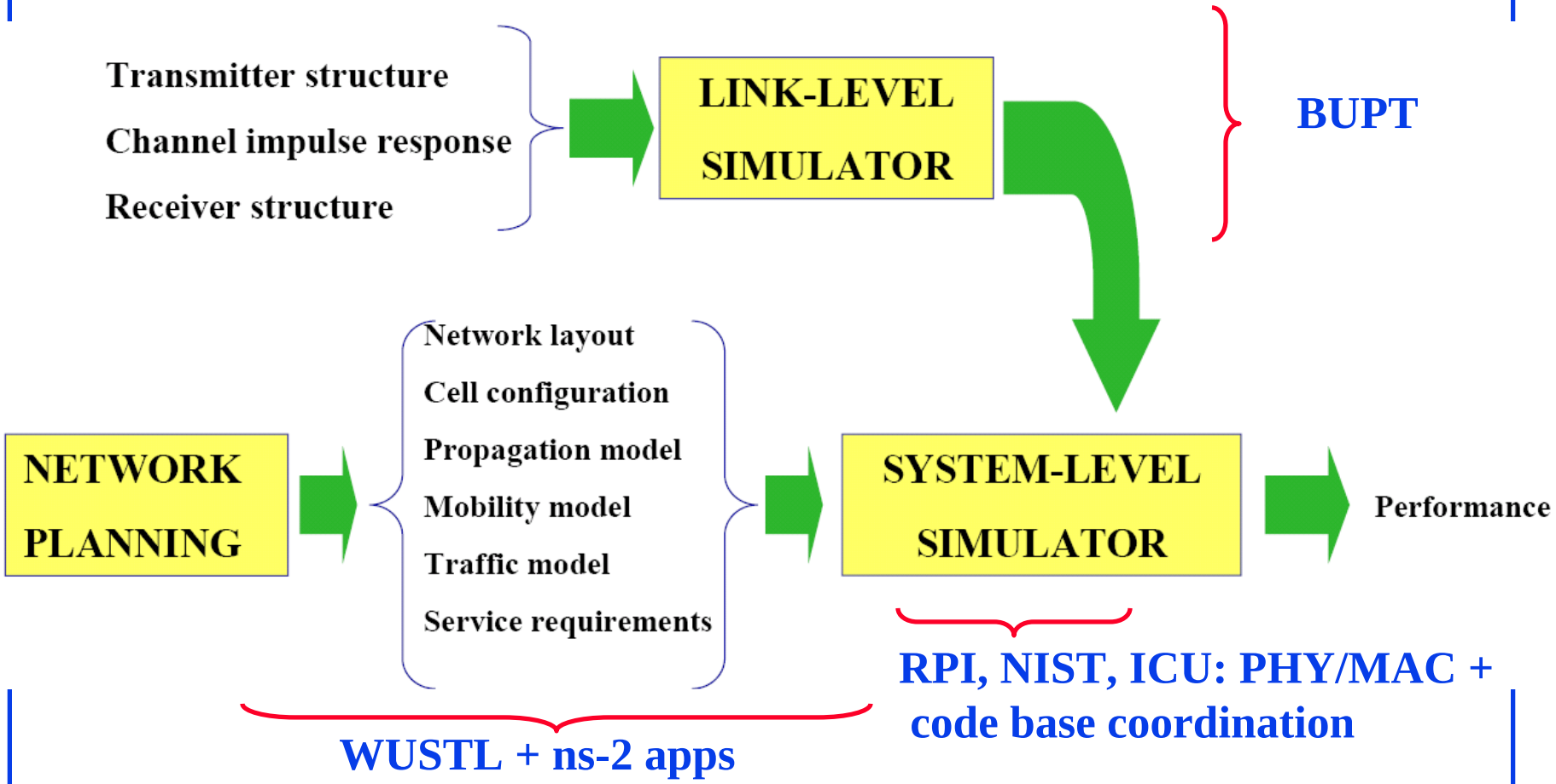
Example: Quake 2 Traffic Model

Session Duration (hour)	Extreme (a=1, b=0.1), Truncated (0, 2)		
Client/Server	Data	Model	
Client to Server	Packet Inter-arrival time (msec)	Lower 4.5%, x<18:Extreme	a=6.57, b=0.517
		Upper 95.5%, x>= 18: Extreme	a=37.9, b=7.22
	Packet Sizes (byte)	Seven Distinct values	10.6%:36, 26.4%: 42, 6.26%: 44, 13.9%: 45, 4.95%: 46, 16.3%: 48, 21.5%: 51
Server to Client	Packet Inter-arrival time (sec)	Lower 4.8%, x<60:Extreme	a=58.2, b=7.47
		Upper 95.2%, x>= 60: Normal	a=100, b=17.7
	Packet Sizes (byte)	Lower 27.6%, x<55:Extreme	a=46.7, b=4.39
		Upper 72.4%, x>= 55: Extreme	a=79.7, b=11.3

University Collaborations

- **Rensselaer Polytechnic Institute (RPI):** Developing the base NS2 simulation model
- **Washington University in Saint Louis (WUSTL):** Methodology, Scheduler, Application performance modeling
- **National Institute of Standards and Technology (NIST):** OFDM, Handover
- **Beijing University of Posts and Telecommunications (BUPT):** PHY abstractions, Link simulation outputs for system simulation
- **Information and Communications University (ICU), Korea:** Analyze WiBro/WiMAX for VoIP and selected TCP applications

System-Level (SLS) vs Link Level Simulation (LLS)



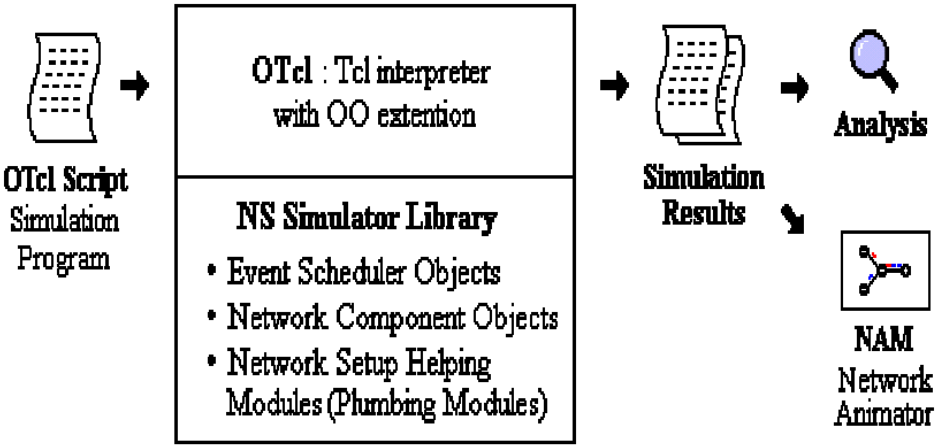
(Based upon Alvarion slides)

System-Level NS-2 Simulator

- **Goal**: Develop the NS-2 modules required for simulating different applications over a WiMAX network, and make them freely available to the public at large
- **Purpose**: Enable vendors, service providers and researchers to conduct extensive system level studies of WiMAX networks through simulations to promote mass deployment of such networks
- **Approach**: AATG is driving this effort by
  - Consulting with universities (RPI, WUSTL, BUPT, ICU)
  - Collaborating with NIST
  - Collaborating with WiMAX Forum members

Why NS2?

- NS2 is a discrete event simulator targeted at networking research.
- NS2 provides substantial support for simulation of TCP routing, and multicast protocols over wired and wireless (local and satellite) networks.
- It is an open source, which entails that it can be used and modified freely.
- It is also one of the widely used Simulator.



Background

- This project started around August 2006 as a collaborative effort of RPI and WiMAX Forum.
- Release 1 was made in December, which had basic features like Service Classes and Single Channel PHY.
- Spring 2007: Collaboration with NIST, which had a very structured standard based OFDM model. RPI code was migrated to the NIST code.
- Aug 2007: Release 2 was made with features like OFDMA PHY and MAC.
- Dec 2007 – Release 3 is scheduled, which will include features like MIMO and Adaptive MCS.

Release 2 – Feature List

- RPI code aligned with the NIST code base for Release 2.
  - Re-implementing release 1 features to fit the NIST model.
- Leveraged NIST features:
  - Time Division Duplexing (TDD)
  - Dynamic Network Entry
  - Allows custom packet classifiers
  - Fragmentation/Reassembly of packets
  - MAC Management messages (DL/UL MAP'S …)
  - Mobility Extension (802.16e)
  - Support for Subscriber Stations (SSs) with different modulations (static, not adaptive)
  - User configurable traffic flows and dynamic connection setup

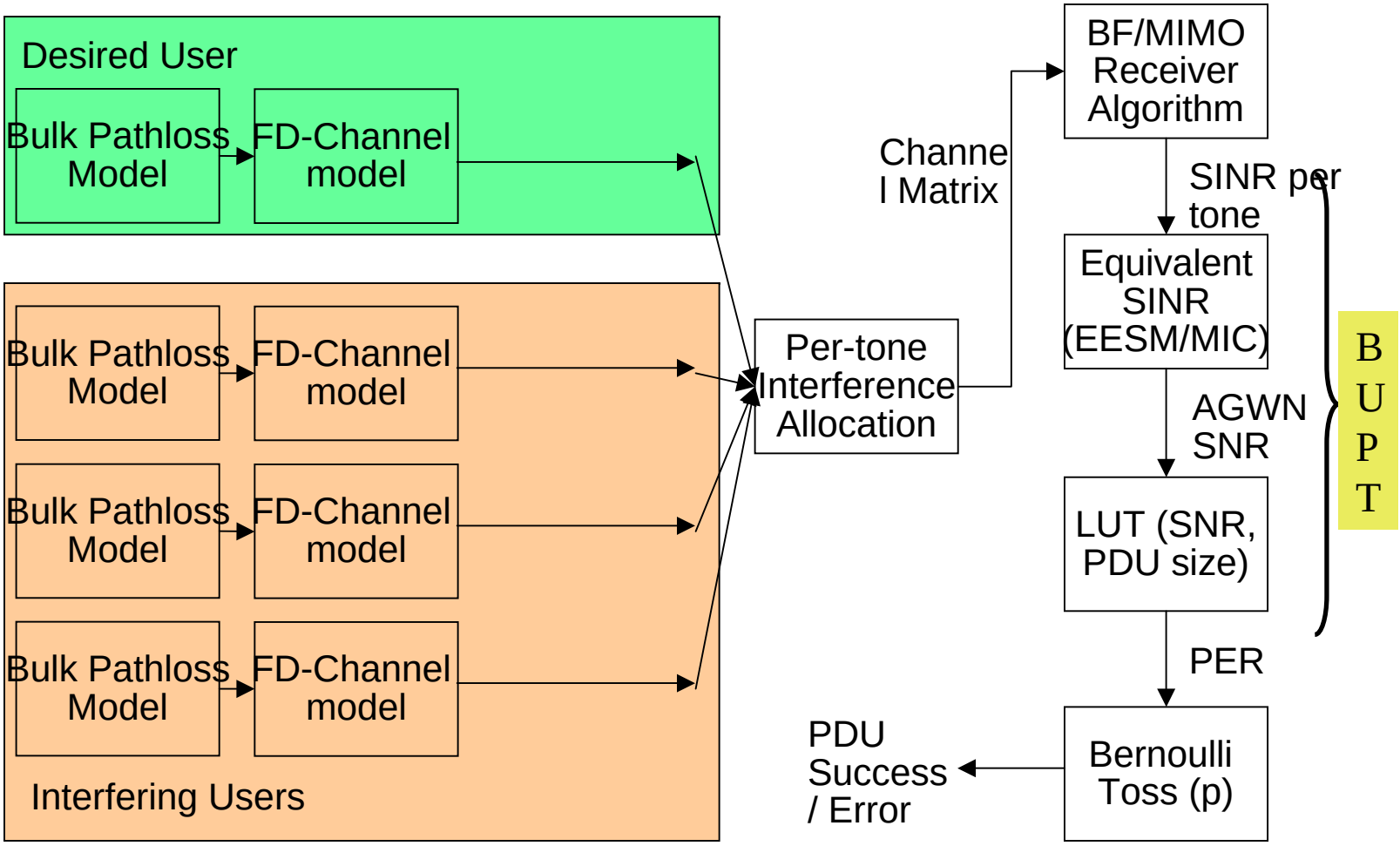
Release 2 features (Cont)

- New physical channel model for OFDMA:
  - Frequency domain model for efficiency
  - Captures time/frequency diversity and aligned w/ ITU models
  - OFDMA implementation
    (NIST code was based upon an OFDM model)
  - 2-D Frame structure.
- MAC features:
  - Scheduler: Basic Round Robin OFDMA Scheduler.
  - ARQ
  - Service Classes: UGS, BE and rtPS.

Release 2 features (Cont)

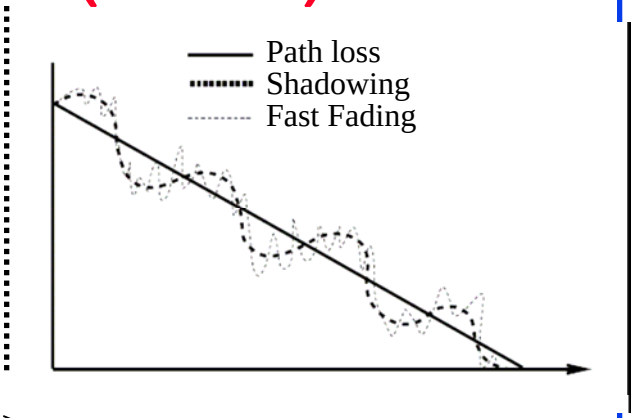
- PHY Abstraction modeling:
  - Interference modeling.
  - EESM based SINR calculation.
  - Link level based BLER calculation.

Block Diagram of Components



(Modified From Dr. Arvind Raghavan, Arraycomm)

OFDM Channel Model (cont.)



Path Loss (COST231 or ERCEG) → Shadowing (lognormal) → Fast/Mpath Fading: Rayleigh, Mpath, Jakes Spectrum

Generate IID Rayleigh Samples (1024) F-domain → Multiply w/ doppler spectrum → Take IFFT: get T-domain Samples (1024) → Scale with Power-delay-Profile (PDP) → Take FFT: get F-domain Samples (1024)

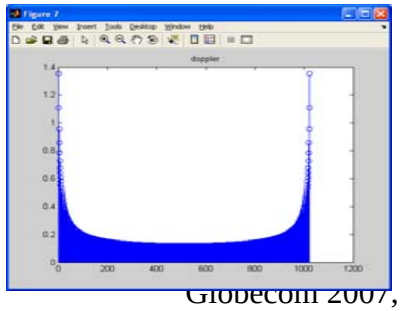
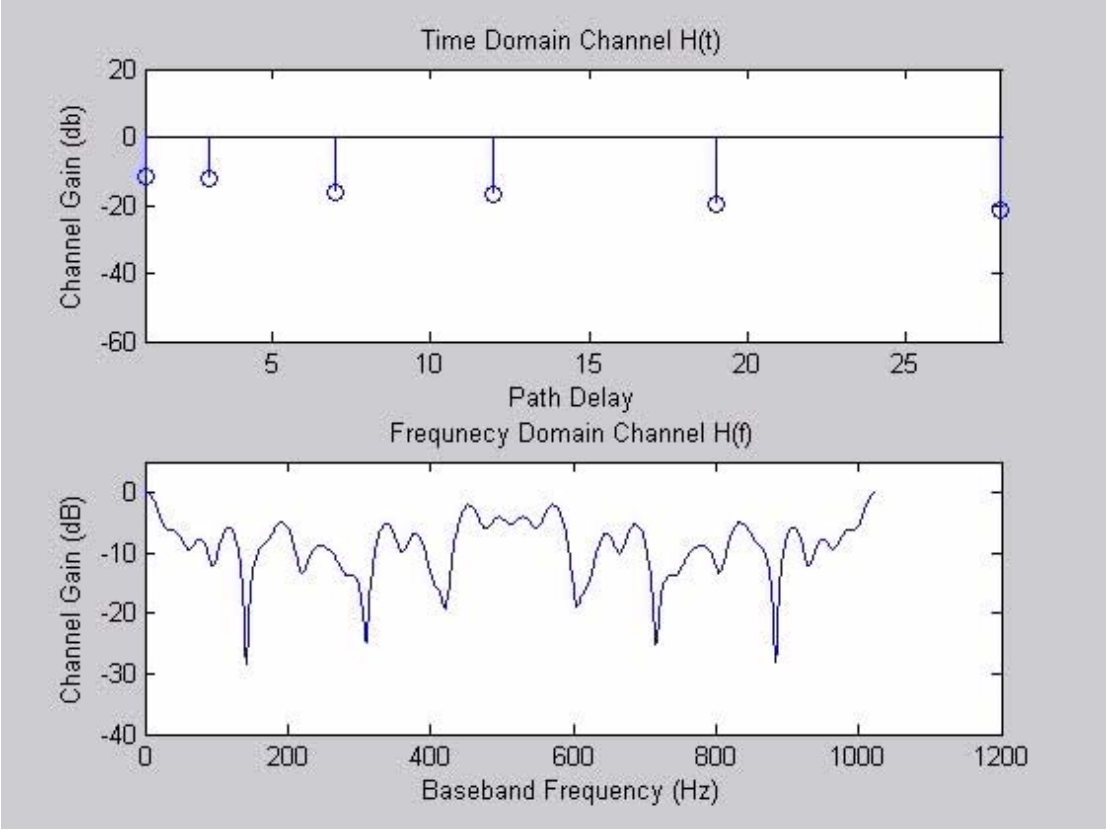


Table A.2.6.3: ITU Channel Model for Vehicular Test Environment

Tap	Channel A	
	Relative delay (ns)	Average power (dB)
1	0	0.0
2	310	–1.0
3	710	–9.0
4	1 090	–10.0
5	1 730	–15.0
6	2 510	–20.0

Sample Snapshot of ITU Veh-A Channel

Each frame is a channel realization that will be used for the channel coherence time (~5ms).



OFDMA frame structure (implemented)

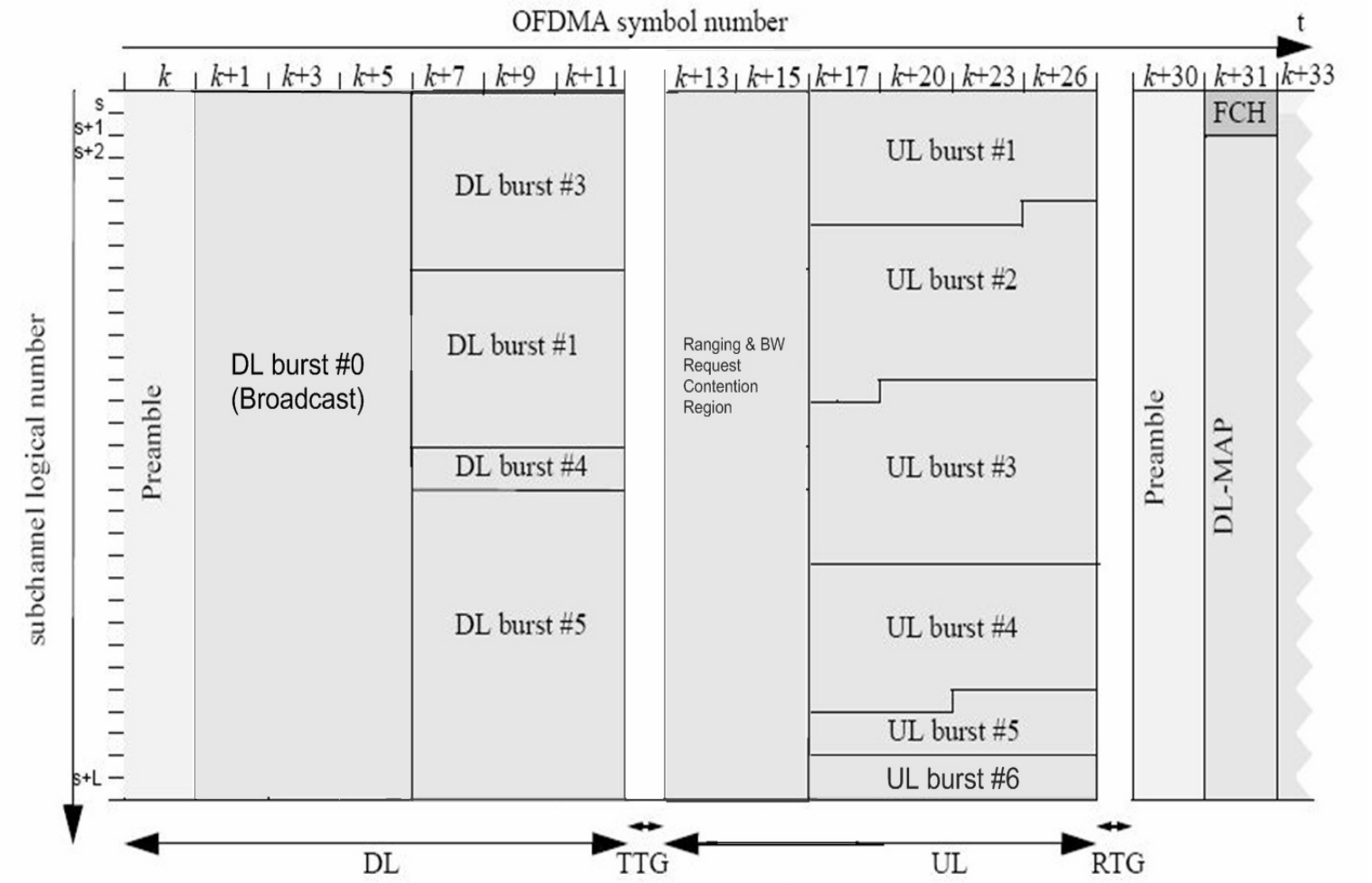
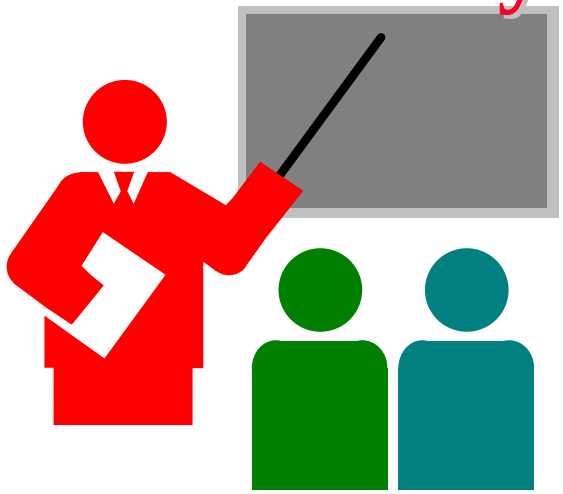


Figure 218—Time plan - one TDD time frame (with only mandatory zone)

Summary



1. System-level ⇒ Multi-cell configuration
2. SLS document provides parameters and methods for simulating various features
3. Covers PHY, MAC and Applications
4. Applies to all simulation tools: NS2, Opnet, Qualnet
5. NS-2 model providing system-level simulation of WiMAX is being developed.