Improving CDMA cellular capacity

SENDILRAMKUMAR DEVAR (EE03D008)

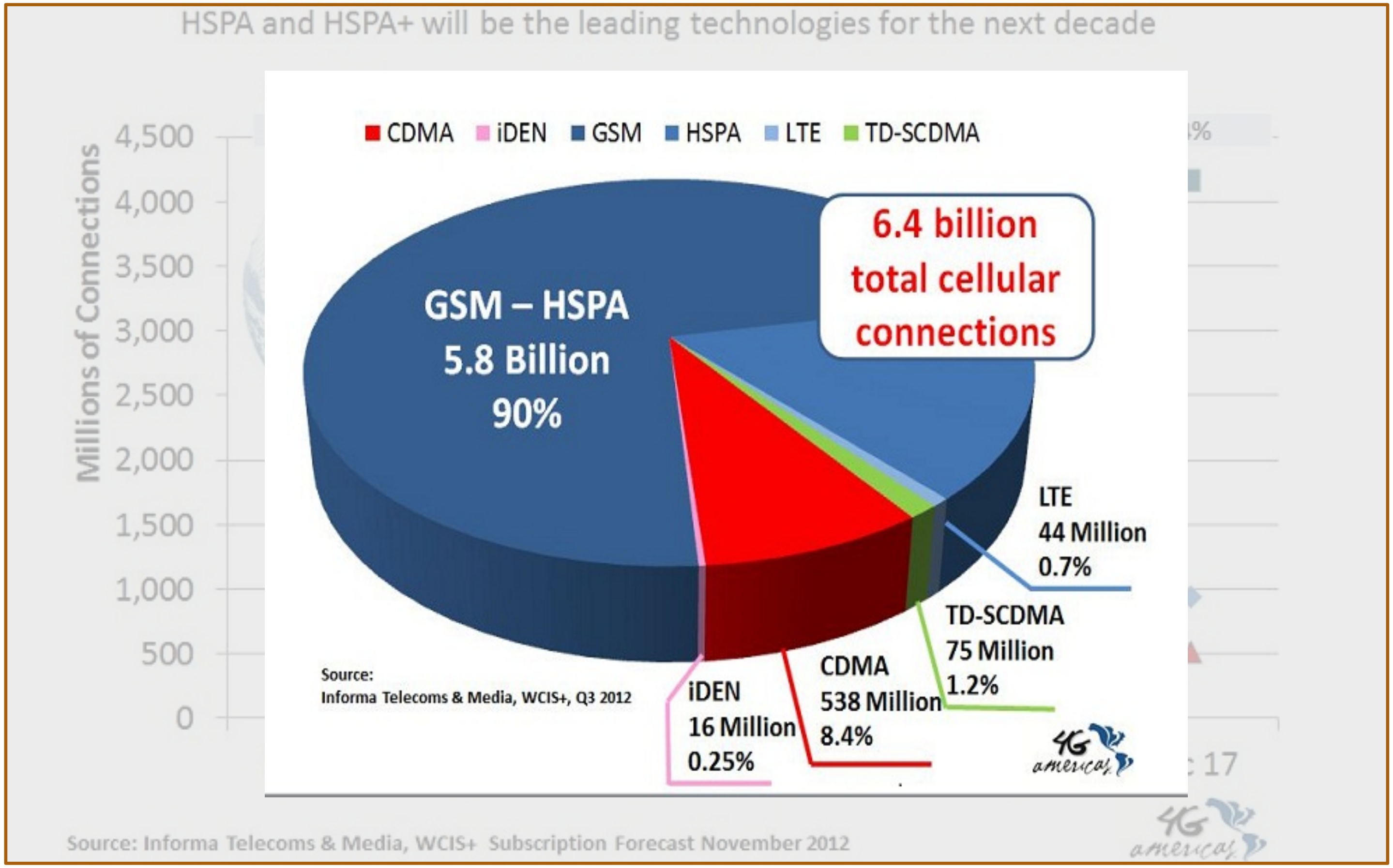
ADVISOR – PROF. DAVID KOILPILLAI

Department Of Electrical Engineering

Indian Institute Of Technology Madras

Part of research was funded by TCOE and CEWIT

3G and Beyond 3G - CDMA



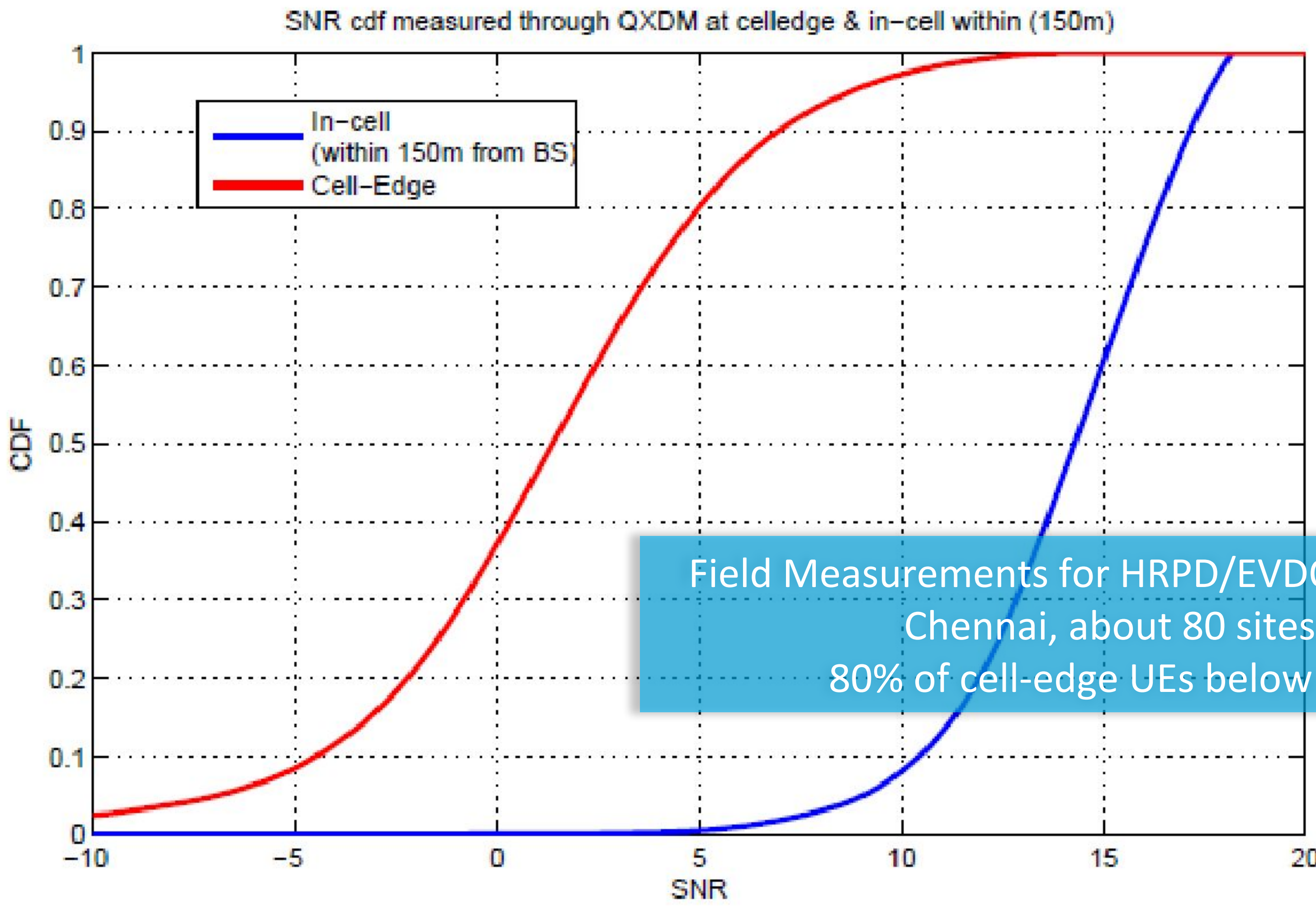
TDMA (GSM)- > CDMA (HSPA, EVDO) -> OFDM (LTE)

Motivation

- Reuse-1 deployment
  - Leading to more cell-edge UEs
  - Reduction of cell's average throughput
- 50-70% of users access packet data from Indoor
  - Degradation of indoor coverage
  - Higher frequency band spectrum – high penetration loss
- Small-cell Solution
- Throughput Enhancement for cell-edge users System Level

Link Level Improvements (Receiver algorithms)	**System Level approaches**

Field Measurements



Field Measurements for HRPD/EVDO systems in Chennai, about 80 sites
80% of cell-edge UEs below 5dB

Inference from Field measurement

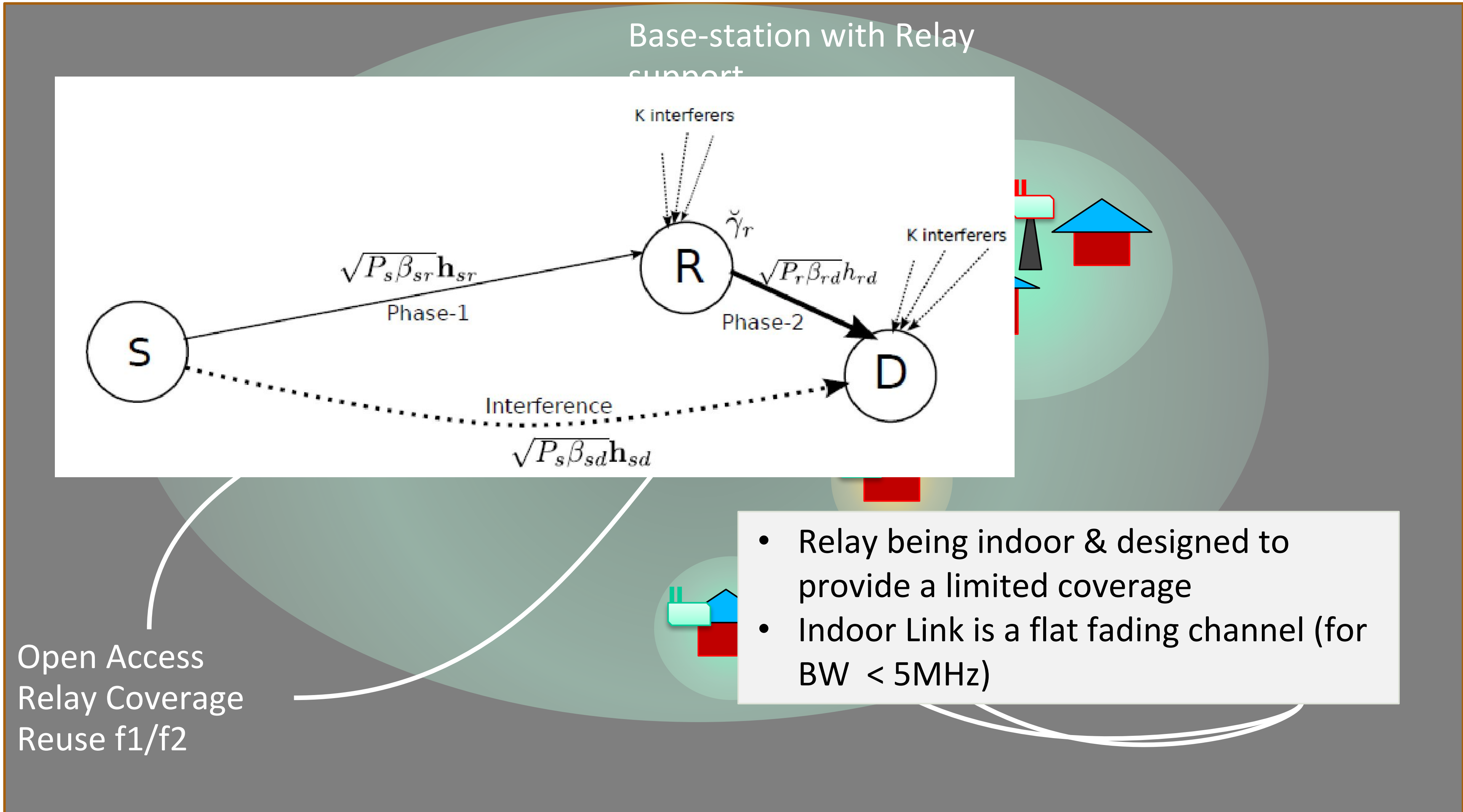
- Most cell-edges UEs are at 5-8dB lower compared to in-cell UEs
- Signal boosting is required for indoor & cell edge
- Interference Cancellation of at least one dominant
- Create a Hot-Spot with high SINR signal at cell-edges

Potential Options : *Repeaters, Relays*

Indoor Throughput improvement

- Typical field measurements are done outdoor
- Small cell solutions
  - Femtocell
  - Pico cell
- Relay based two-hop solution
  - **User Deployable** - deployed by the user, no specific requirements like LOS needed
  - **Transparent Relay** - appears as conventional macro-BS in the network and hence transparent to the UE (backward compatible with legacy UEs)
  - **Concurrent Relaying** : The BS and the relays of a cell can transmit simultaneously, on the same carrier.

Indoor Relaying



- Relay being indoor & designed to provide a limited coverage
- Indoor Link is a flat fading channel (for BW < 5MHz)

Issues

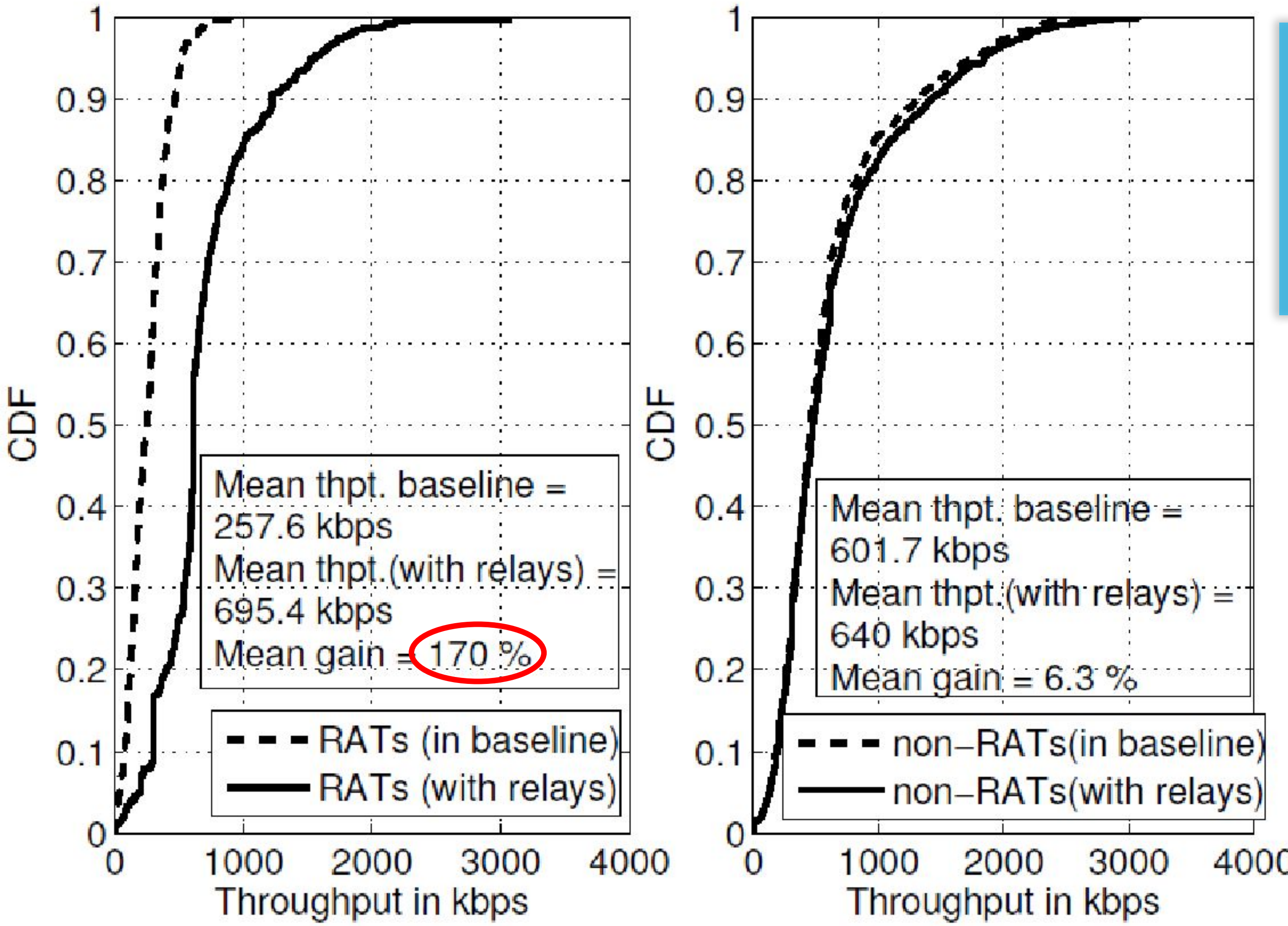
In-band relaying

- Interference to Relay-served
- Interference to macro-served

Deliverable SINR to Relay served indoor UE

- Relayed signal : Equalized signal and residual Interference
- Forwarded interference
  - Input signal strength
  - Capability of interference suppression
- Increasing Relay Power : Increases forwarded interference

Throughput results

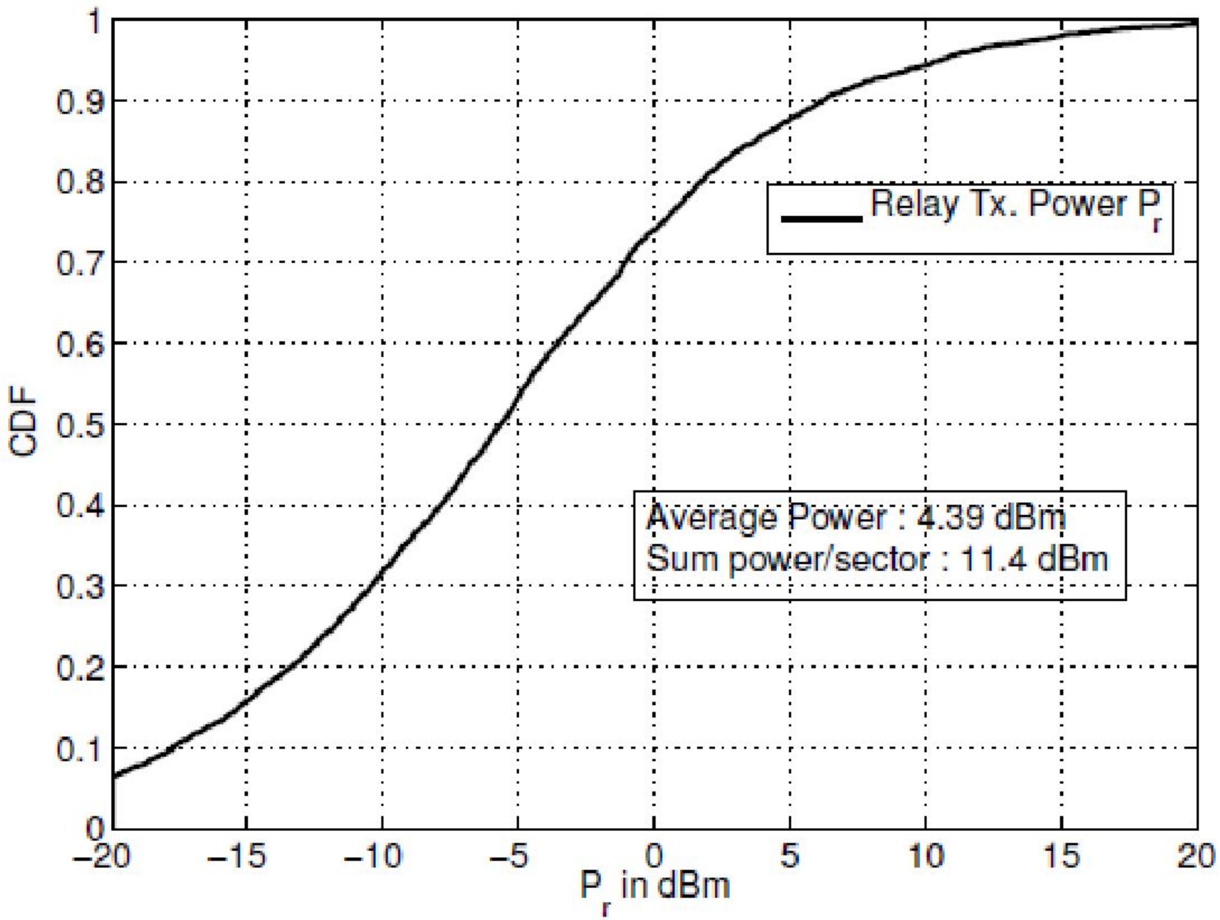


RAT :

Relay-served

Access Terminal

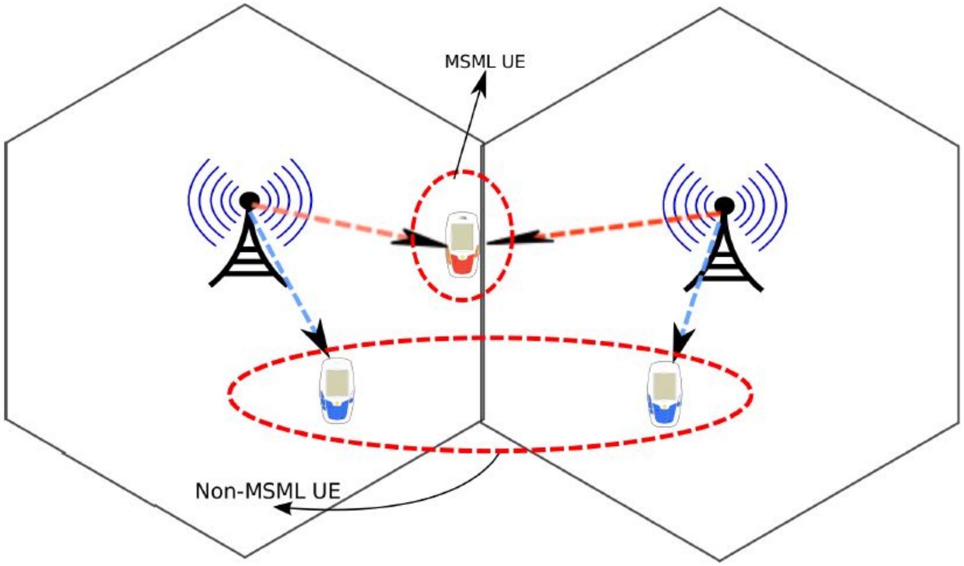
Relay Transmit power



Relay's Transmit power optimized through proposed algorithm

Cell-Edge Performance Enhancement

- Low throughputs experienced by users located at cell-edge
  - Poor SINR
  - High Interference due to Reuse-1
- Known Techniques to improve cell-edge experience
  - Advanced Interference aware receivers
  - Multi-carrier transmission
  - MIMO, Beamforming
  - …
  - ***MSML – Multi-link Multi-Streaming***



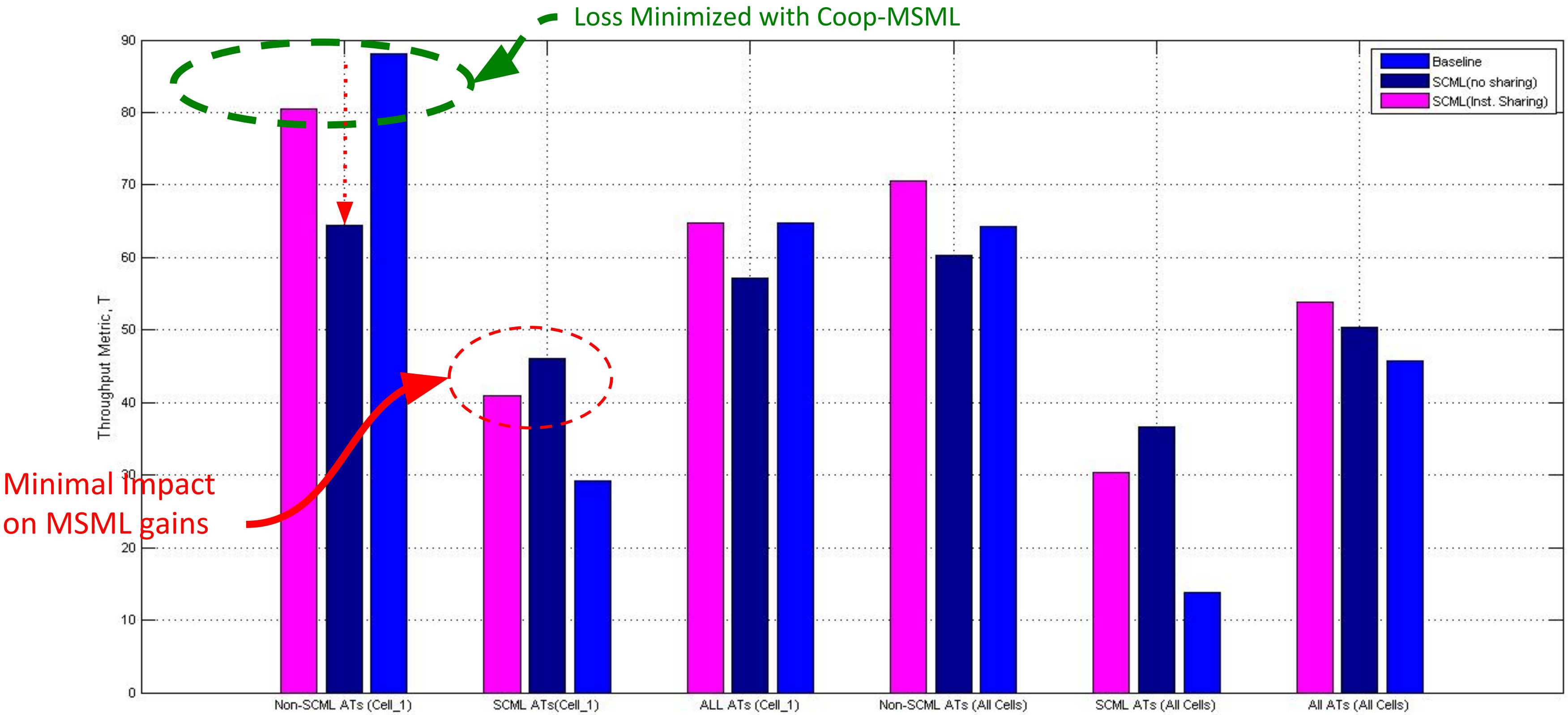
System Tradeoff

- **Additional links at the server to cater to MSML UEs in neighboring cells**
  - Larger contention for the downlink resources
  - Non-MSML UEs lose scheduling opportunities
    - Only experience the contention with no additional links serving them
    - Unlike MSML UEs, where additional link compensated increased contention
- **Negative Impact to Non-MSML UEs**
  - May lead to loss of throughput
  - Reduction in fairness of scheduling
- **Negative Impact to overall cell throughput**
  - Non-MSML (in-cell, high SINR) UEs are major contributors to cell throughput
  - Reduction in throughput to Non-MSML UEs offsets gains to MSML UEs

Solution

- Balance the tradeoff
- Exploit “maneuvering room” present in the variety of real-life deployments
  - Less than full resource utilization *(e.g. intermittent and bursts data traffic as in the case of web browsing)*
  - Imbalance load between neighboring cells *(in the short, as well as the long time scales)*
- Information Exchange - between participating base Stations
  - Throughput delivered from either Base Station
  - Load (number of users) at each Base Station
  - Channel Quality Ensemble for users that are in these multiple scheduling pools
  - Deployment Scenario dictates what information to share (use)
    - E.g. can do traffic re-routing either based on Load Imbalance, or Operator Policy

Co-operative scheduling



- Without Co-operation - Non-MSML UEs suffer losses w.r.t to the baseline
- With Co-operative scheduling, Loss to Non-MSML UEs is reduced without significant reduction in SCML gains to MSML UEs.

Summary

- MSML leads to *gain for cell-edge users* (that can get into MSML mode)
- Non-MSML users *suffer losses during MSML* operation – cost of gain for cell-edge users
- Cooperative scheduling based on feedback sharing can be used to control the tradeoff
  - Losses to Non-MSML users can be reduced
  - Feedback sharing can be used *to balance gains* between the Non-MSML and MSML users
- The gains to MSML users due to feedback sharing at *different periodicities* are *comparable* same as with instantaneous throughput sharing
  - Feedback sharing periodicity can be tuned based on considerations of backhaul requirements

A mechanism and framework for feedback sharing over the backhaul was proposed by the authors and has been accepted into 3GPP2 standards.

Contributions of Thesis

- User-deployable relays with Equalize and Forward relaying was studied.
- Interference management schemes for concurrent relaying were presented.
- Self-Organizing Procedure was proposed to help in managing the provisioning of relays in the network.
- Framework for enabling the proposed two-hop relay-based small cells within the existing HRPD network was proposed.
- Fairness metric was proposed which aided the significance of trade-off between SCML gains to the cell-edge UE and fairness to other UEs in the cell.
- A co-operative scheduler was proposed to control this trade-off.
- In addition to the system-level approaches for improving capacity on the downlink, we also proposed a Widely-Linear receiver algorithm for STTD reception.
- Impact of downlink transmission with single and multiple antenna methods, Simultaneously in the same slot was studied.

Patents – PCT Filed

1. **Sendilramkumar Devar**, Bhaskar Ramamurthi and David Koilpillai, *"Method of Interference Management for cell-edge users in CDMA systems"*, Ref. 2922/CHE/2010

2. **Sendilramkumar Devar**, Nadeem Akhtar and Bhaskar Ramamurthi ,*"Enhancements to a CDMA system to support in-band personal indoor relays"*, Ref. 2815/CHE/2010

3. **Sendilramkumar Devar**, Nadeem Akhtar and Bhaskar Ramamurthi, *"Interference Management in a Heterogeneous CDMA Cellular Network"*, Ref. 1402/CHE/2012

4. Nadeem Akhtar and ***Sendilramkumar Devar*** *"Multi-RAT Relay"*, Ref. 1375/CHE/2012

5. Arun Ayyar, ***et al.***, *"Interference Cancelling Block Modulation"*, PCT/IN2011/000250, WO/2011/125076.

Publications (1/2)

Journal

- ***Sendilramkumar Devar***, Karthik K.S, Bhaskar Ramamurthi, David Koilpillai, *“Downlink Throughput Enhancement of a Cellular Network using Two-Hop User-Deployable Indoor Relays”*, IEEE Journal on Selected Areas in Communications, (To appear Aug 2013)

Conference

- 1. ***Sendilramkumar Devar***, Satish Kanugovi and Subramanian Vasudevan,*“Co-operative scheduling for balancing throughput gains and fairness in cell-edge enhancement schemes for wireless networks”*, Communication Systems& Networks (COMSNETS 2013), Bangalore, January 2013.
- 2. J. Vinosh Babu James, V. Ganesh and ***Sendilramkumar Devar***, *“Challenges in the design of a broadband wireless system: a 3GPP perspective”*, Proceedings of MOWITS 2009
- 3. ***Sendilramkumar Devar*** and R David Koilpillai, "Equalization technique for HSDPA receiver with pure transmit diversity", Wireless World Research Form, Stockholm, Sweden. October 2008.

Publications (2/2)

- 4. ***Sendilramkumar Devar***, Vinosh Babu James and R. David Koilpillai, *“Modified Transmit Diversity Technique to Facilitate Unified receiver for wide-band CDMA system”*, Wireless Personal and Multimedia Communications, 10th International symposium, (WPMC 2007), Jaipur, India, 2007
- 5. ***Sendilramkumar Devar*** and R. David Koilpillai, *“Enhanced receivers for High Data Rate CDMA systems”*, Wireless Networking Summit (WiNS) 2006, Goa, India. 2006.
- 6. ***Sendilramkumar Devar***, Garg Mudit and R. David Koilpillai David, "Methods for reducing residual ISI in RAKE receiver for DS-CDMA downlink", National Conference on Communications, IIT-Delhi, 2006.

MSML

Improve cell-edge throughputs

- Create multi-server diversity (more serving links to MSML UEs)

Low complexity solution for 3G networks (among current proposals)

Exploit headroom when cells are not fully utilized

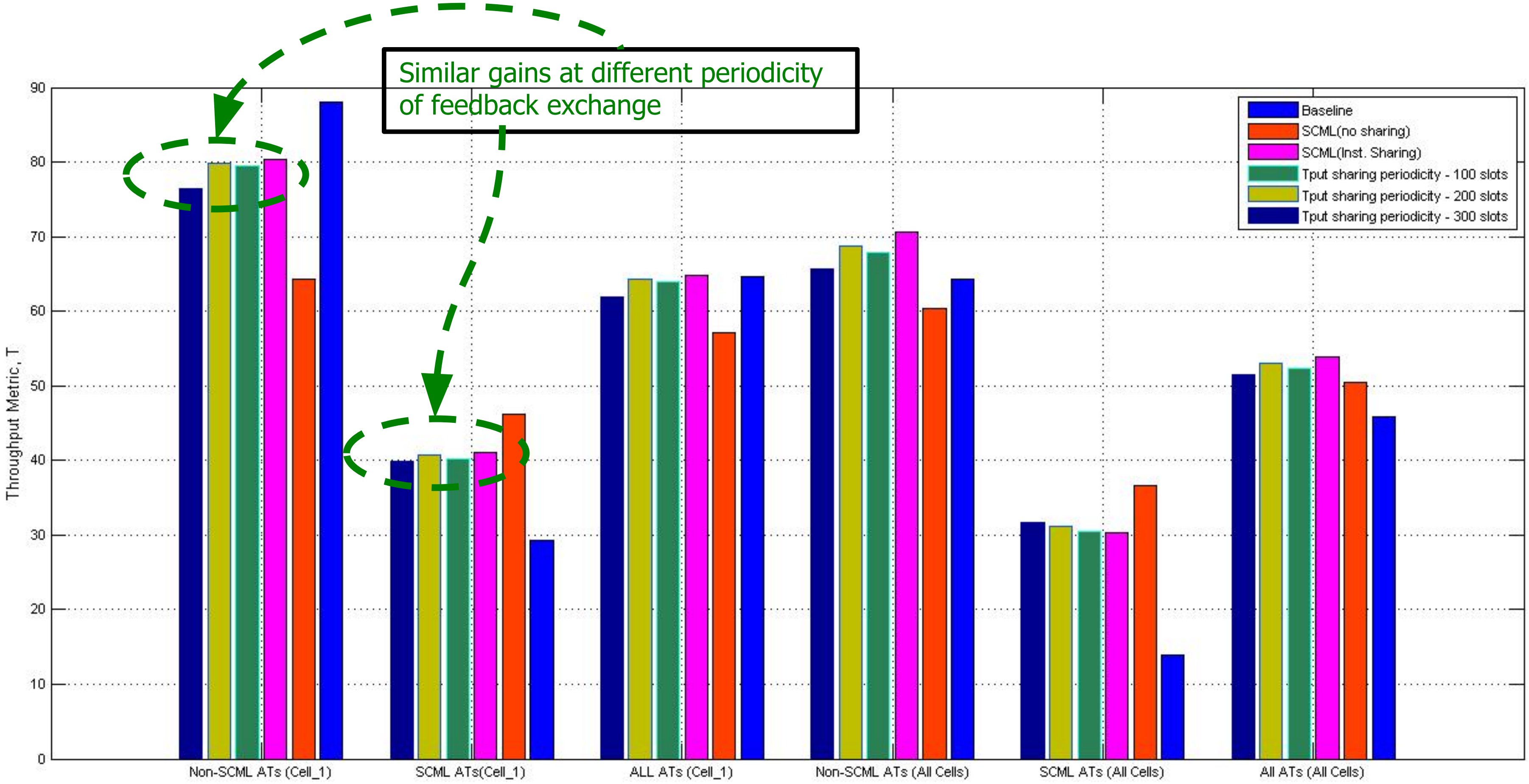
- For ex: spatial imbalances (a cell may have high user density, while some of its neighbors may have low/sparse user density)

Create/increase cell overlap to increase scheduling pool sizes

- Improve multi-user diversity (the scheduler has more MSs to schedule)

Does Multi-Streaming increase overall system spectral efficiency (along with improved cell-edge efficiency)?

Comparison of throughput metrics for different periodicities of feedback exchange



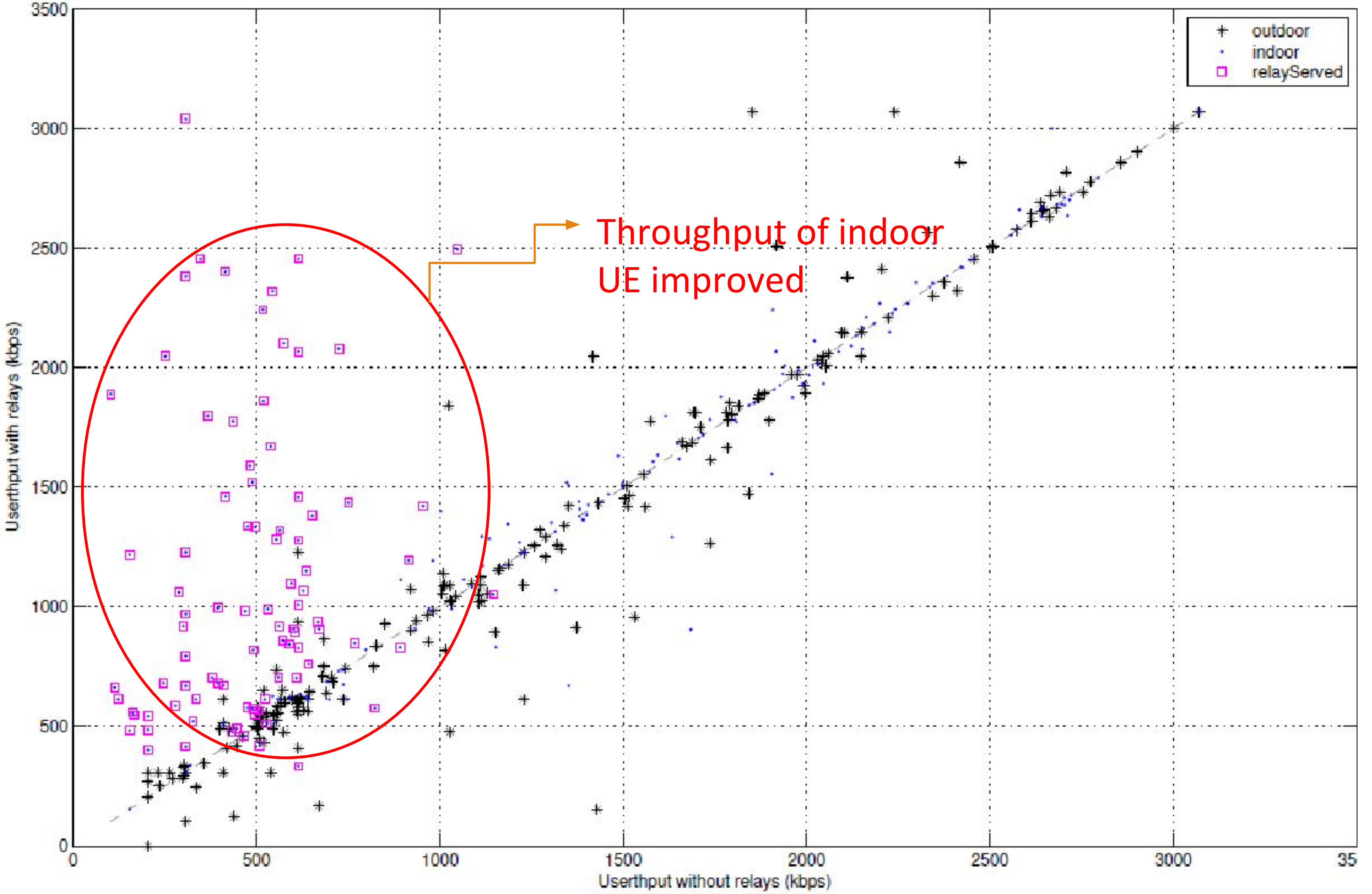
Simulation Parameters

#	DESCRIPTION	PARAMETER
1	Cell Layout	7-cells, 21 sectors, wrap-around
2	Large scale terrain model	Urban Macro , (COST 231 from 3gpp2)
3	Tx Power, Height, Antenna Tilt, Antenna Gain	40 dBm, 32m, 4degree, 15dB
4	Inter Site Distance	1.2 km
5	UE Height	1.5m
6	Carrier frequency (fc)	2GHz
7	No. of carrier per sectors	1 (1.25MHz)
8	Maximum allowed active users/sector	20
9	AT distribution	Spatially Uniform distribution across the cell
10	**AT numbers across cells**	**Heavily loaded cell: 20 ATs per sector** **Lightly loaded cell: 8 ATs per sector** **Cell 1 is heavily loaded, Remaining cells are lightly loaded.**
11	AT mobility	Vehicular speeds distribution per the 3GPP2 evaluation methodology, C.R1002-B
12	**Max. forward links per user in SCML mode**	**2**
13	**T_ADD between active connection to enable SCML**	**<= 6dB**

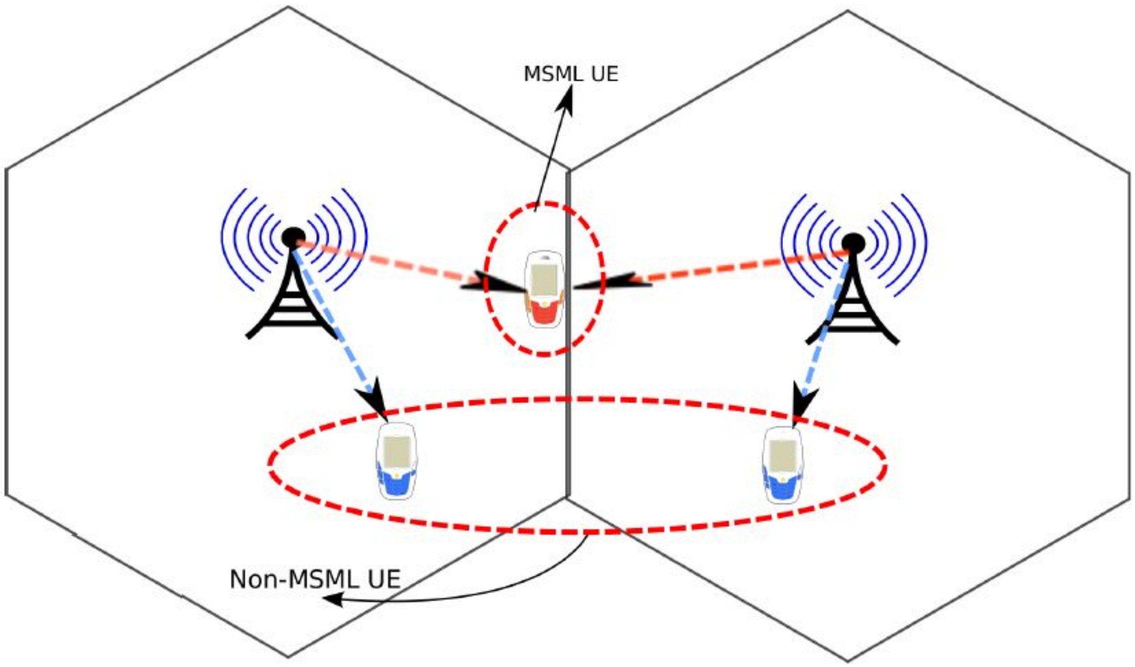
Simulation Parameters

#	DESCRIPTION	PARAMETER
14	Fast Fading Channel Models between Tx and Rx	3GPP2 Channel Mixer 3GPP2 C.R1002-B Evaluation Methodology
15	SCML Source Switching	Disabled AT does not change the SCML sources.
16	Traffic profile	Full Buffer
17	Scheduler	Proportional Fair (Independent at each Sector)
18	Proposed Schemes to be compared	
	Baseline(Independent (PF) schedulers at the SCML sources)	PF_metric(n) = R(n)/A(n), for the nth slot R (n) = Requested Rate based on DRC applicable at the nth slot A(n) = Avg. throughput delivered to the AT at the nth slot
	SCML with instantaneous throughput exchange	PF_metric(n) = R(n)/A(n), for the nth slot R (n) = Requested Rate based on DRC applicable at the nth slot A(n) = A(n) + A_r(n) A_r(n) = Received value of Avg. Throughput delivered to the AT through the other sector
	SCML with periodic throughput exchange	PF_metric(n) = R(n)/A(n), for the nth slot R (n) = Requested Rate based on DRC applicable at the nth slot A(n) = A(n) + A_r(x), x = floor(n/p) where p is periodicity of exchange A_r(n) = Received value of Avg. Throughput delivered to the AT through the other sector

Throughput Impact - relaying



MSML system



Packet Network

- Capability of allowing two or more cells (multi-link) to concurrently schedule independent transmissions (multi-stream) to a UE
- UE present in scheduling pools of multiple servers UE reconstitutes multiple streams of data