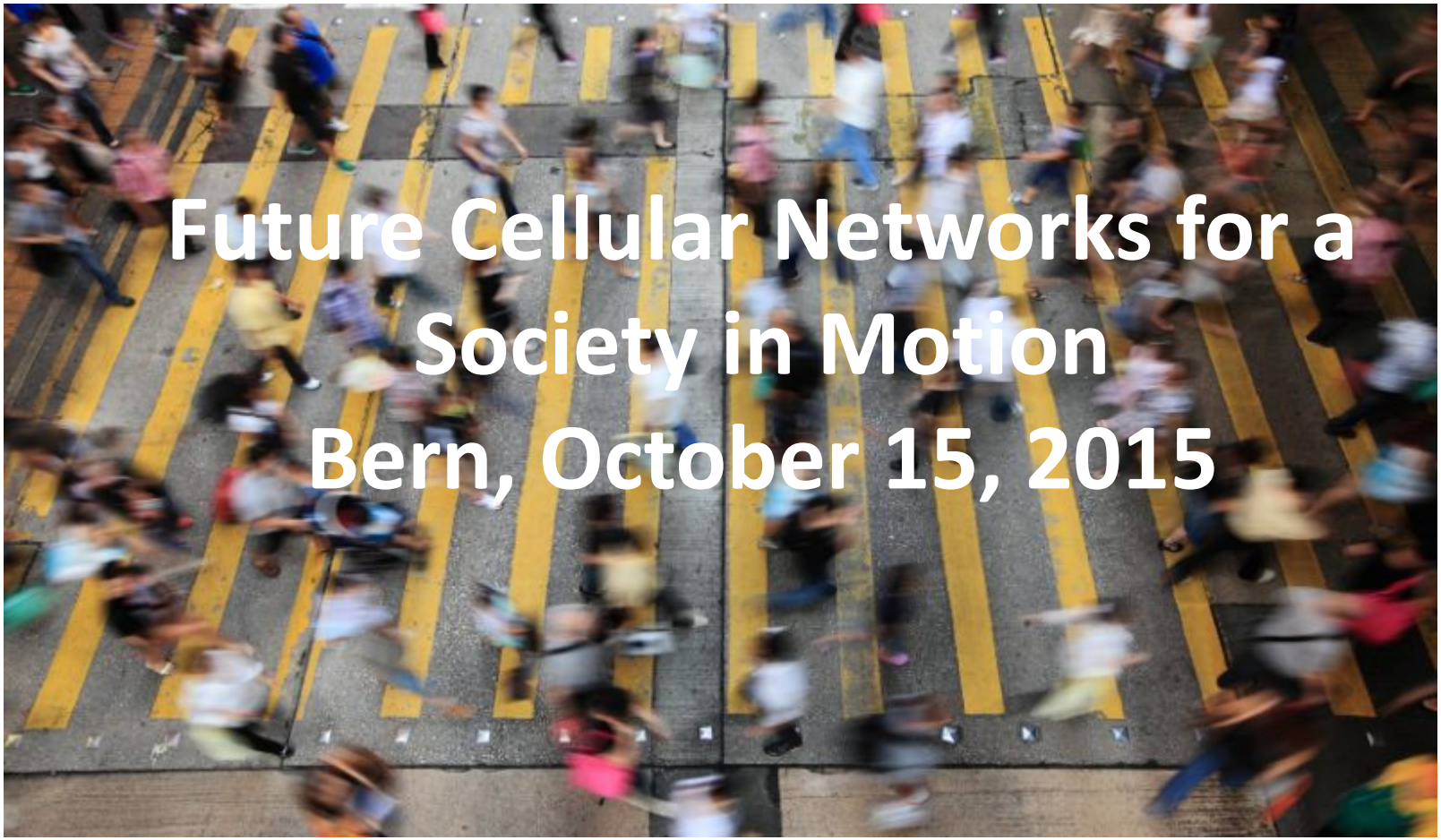


Future Cellular Networks for a Society in Motion
Bern, October 15, 2015

Markus Rupp, Stefan Schwarz

institute of telecommunications

TU Wien

A look into our future

- Mark Twain:
  Prediction is difficult
  – especially for the future

- The UN expects that by 2050 about 86% of the worlds population lives in cities.

  Thus number of cities and city sizes will grow

- This new life-style will also have a deep impact on wireless communications!

A look into our future

- In 2050 we will have only two different scenarios for wireless cellular systems:

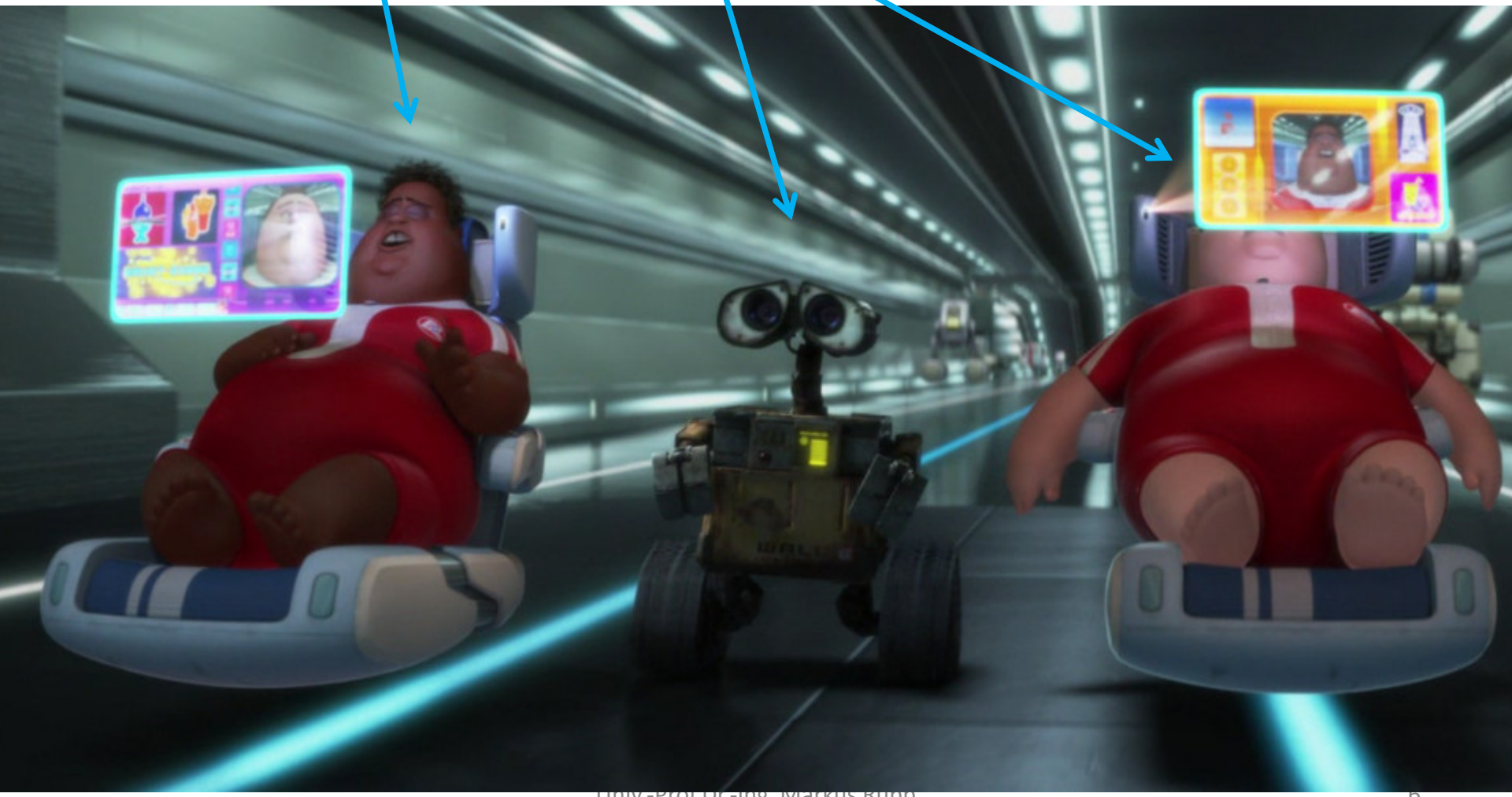
- 1) Nomadic (quasi-static) use
- 2) People and Devices are on the move

A look into our future

- **Nomadic (quasi-static) use** for people in or around buildings. Buildings provide wireless infrastructure just as they do today for water and energy.
- Small picocells (possibly by light) ensure high data rates and low latencies.
- Also along streets, i.e., in cable ducts as Swisscom is currently trying.
- In cities such dense infrastructure can replace the backhaul and allow for low latency!
- Your next BS is less than 5m from you!

Are We All Becoming Mobile, App-Armed Superheroes?

2) People and Devices are on the move



A look into our future

- 2) People and Devices are on the move:
  - Public transportation
    - such as Trains, Busses, Subways, Trams, Airplanes
  - Individual Traffic
    - Cars2go, rental cars, delivery services,
    - governmental services such as police, fire trucks, emergency vehicles
- The choice of transportation means is less and less defined by transportation time and more and more defined by internet access!

A look into our future

- What data traffic is generated in 2050?

- People will serve the internet for
  - Relaxation (music, videos, gaming)
  - Information (news, time tables, etc.)
  - Preparation (before and after work)
- Machines will serve the internet for
  - Traffic control, safety, traffic logistics

A look into our future

- A Society in Motion thus requires a Dependable Internet Service (DIS)
  - Various data traffic requires different rates and latency constraints to function properly

- The challenge is to offer such DIS
  - Everywhere
  - Cost efficiently
  - Reliably

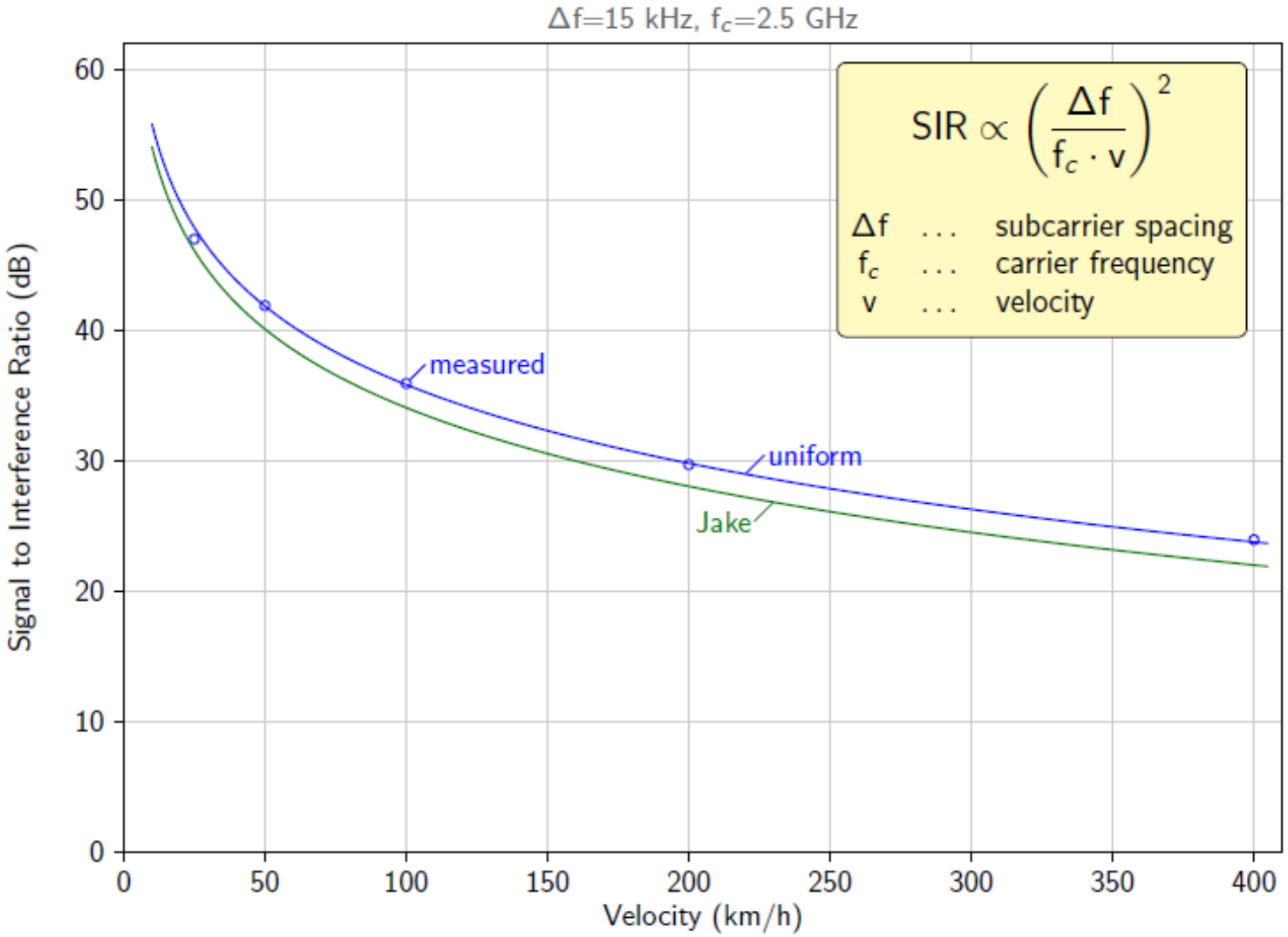
Outline

- Motivation (is already over…)

- High Velocity Challenges
- evolved Multimedia Broadcast Multicast System
- Distributed Antennas
- Heterogeneous Networks

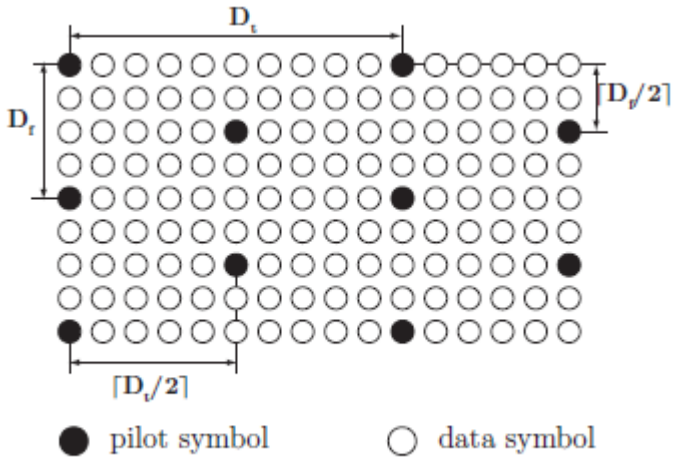
- Conclusions

High Velocity Challenges

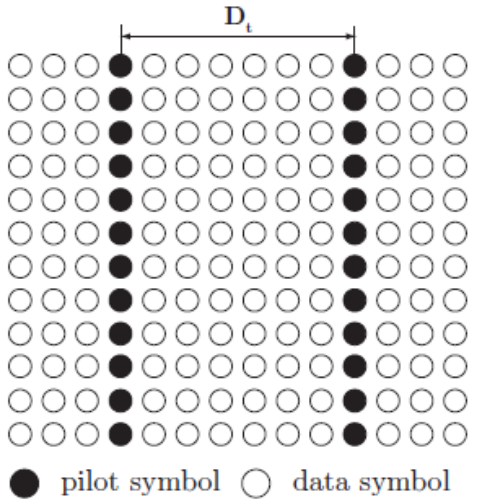
- 

High Velocity Challenges

- Single Pilot Pattern
- One for DL
- One for UL

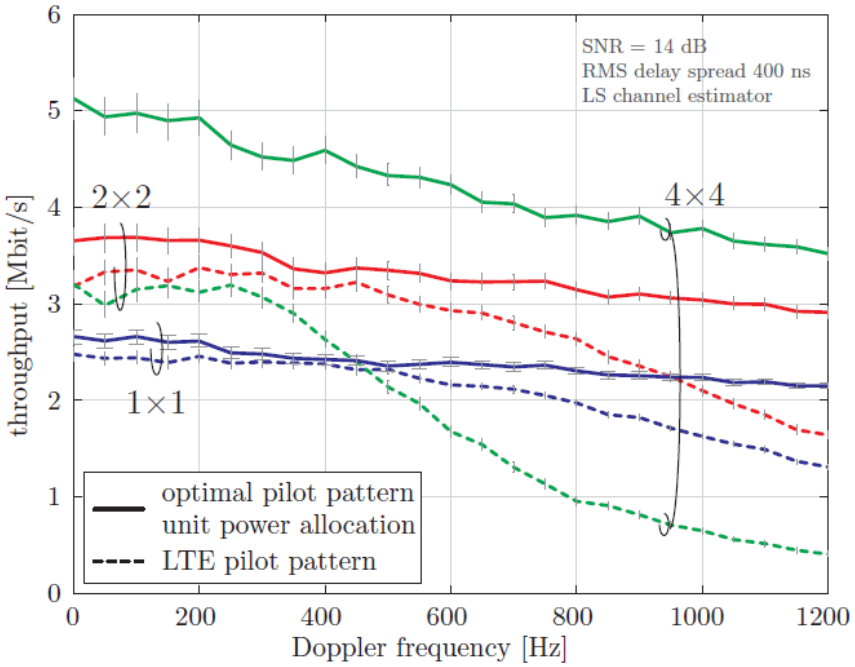


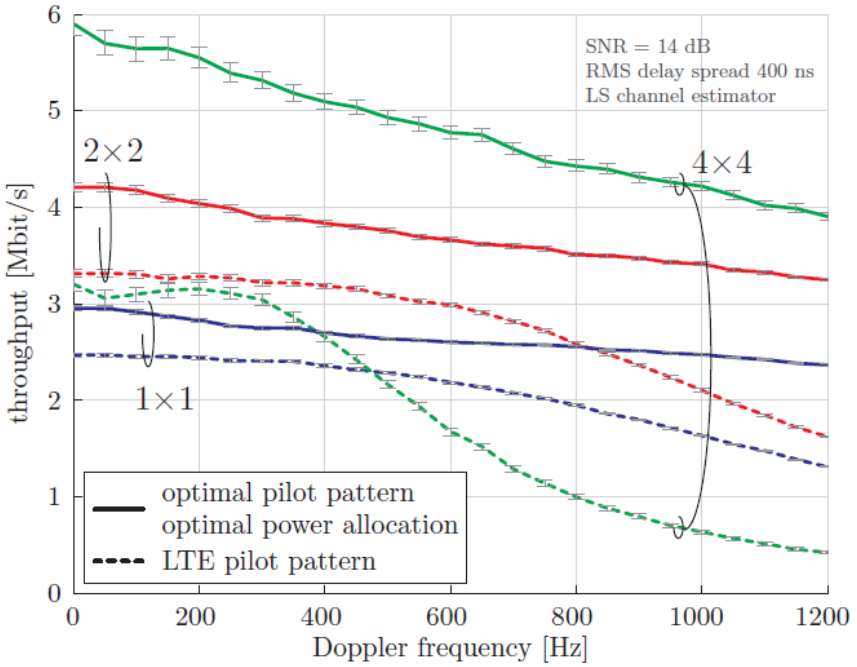
- Independent of
  - RMS delay spread
  - **RMS Doppler spread**



High Velocity Challenges

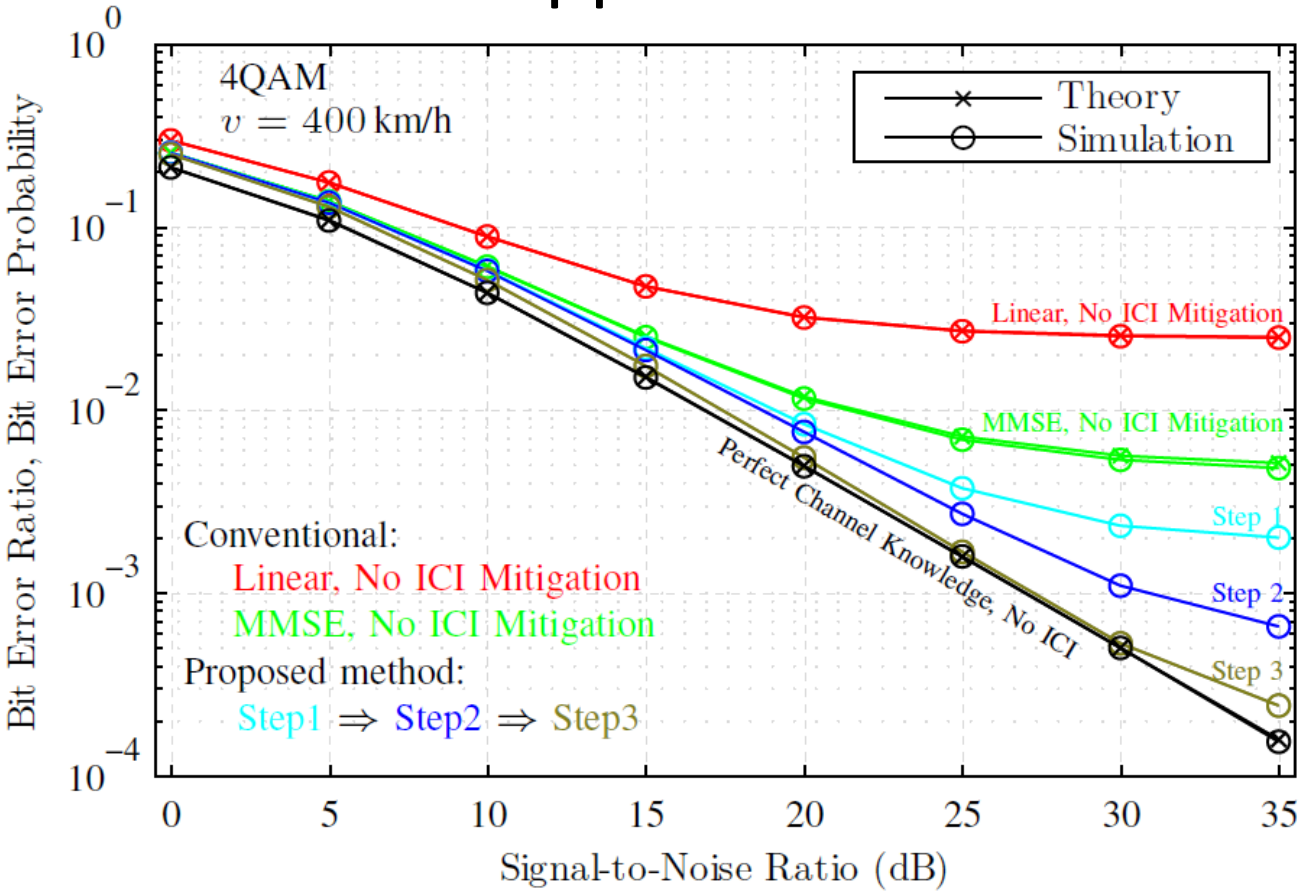
- Optimal pilot pattern and power allocation





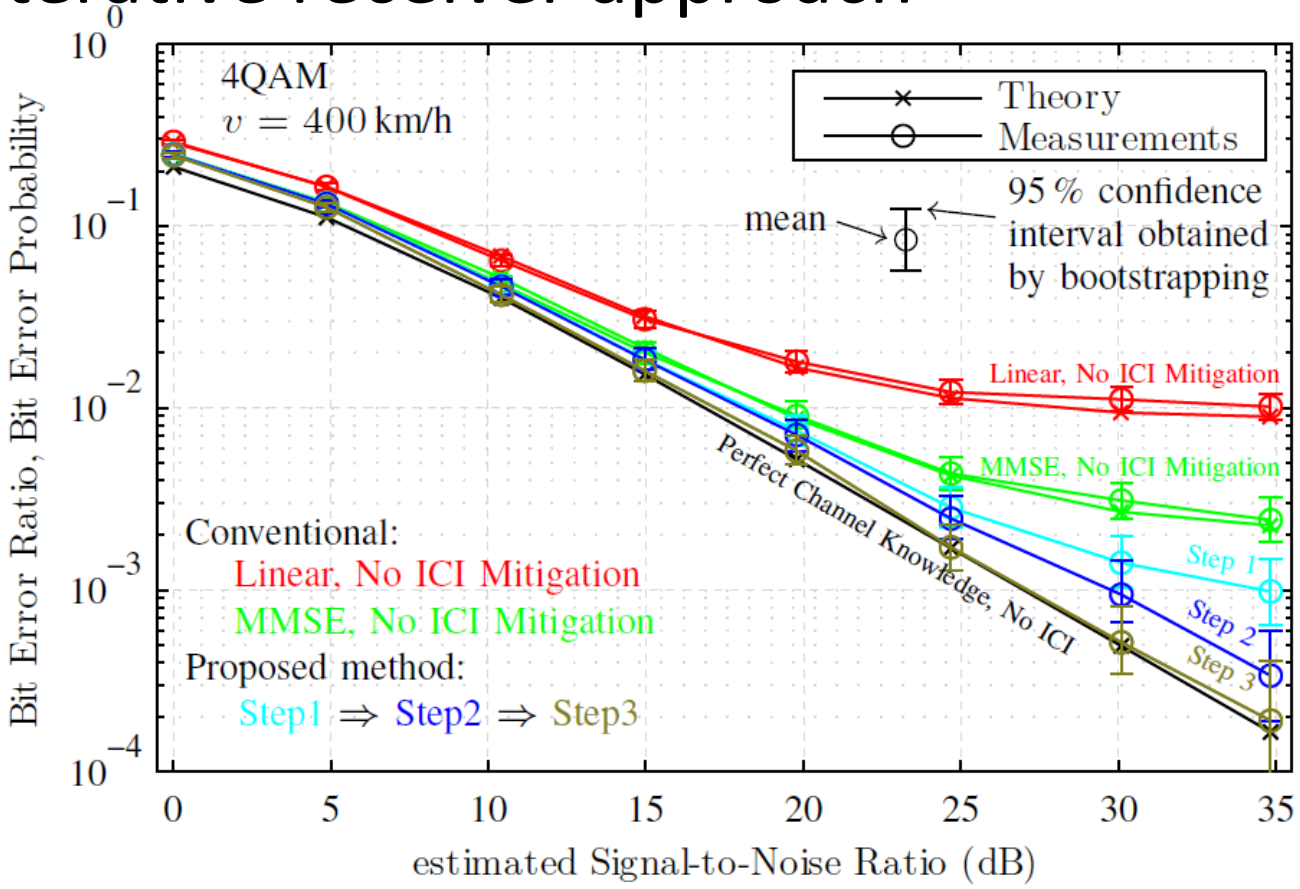
High Velocity Challenges

- Iterative receiver approach



High Velocity Challenges

- Iterative receiver approach



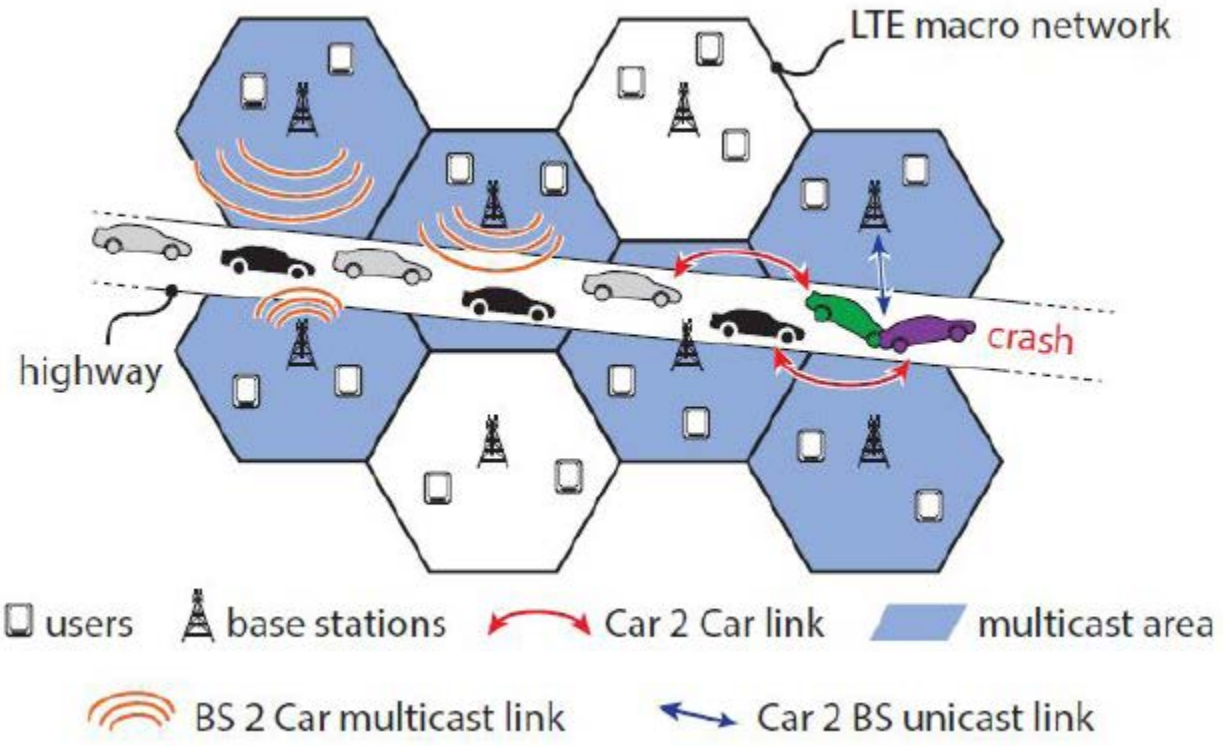
High Velocity Challenges

- OFDM can be improved considerably by
  - Optimal pilot pattern
  - Optimal power allocation
  - Iterative receiver approaches
- 5G proposes Filter Bank Multi Carrier (FBMC)
  - Higher spectral efficiency without CP
  - Can directly match user velocity constraints
  - Can address users with different velocities
- Differential Modulation still not advancing

eMBMS

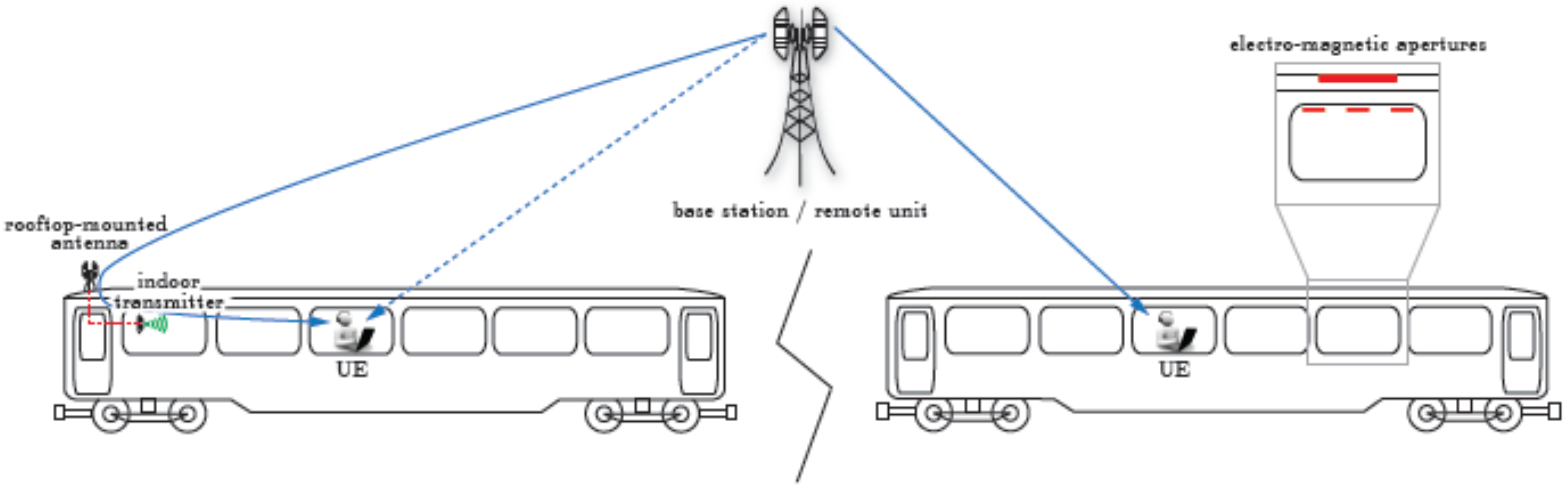
evolved Multimedia Broadcast Multicast System

- Along motorways



eMBMS

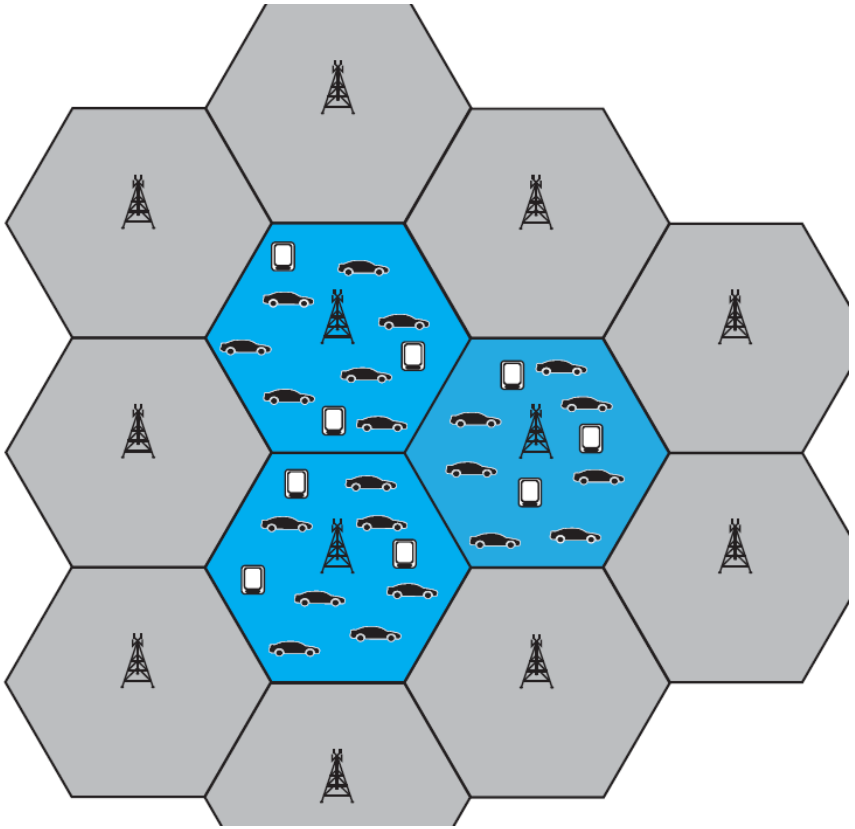
- Along train tracks



Experiment

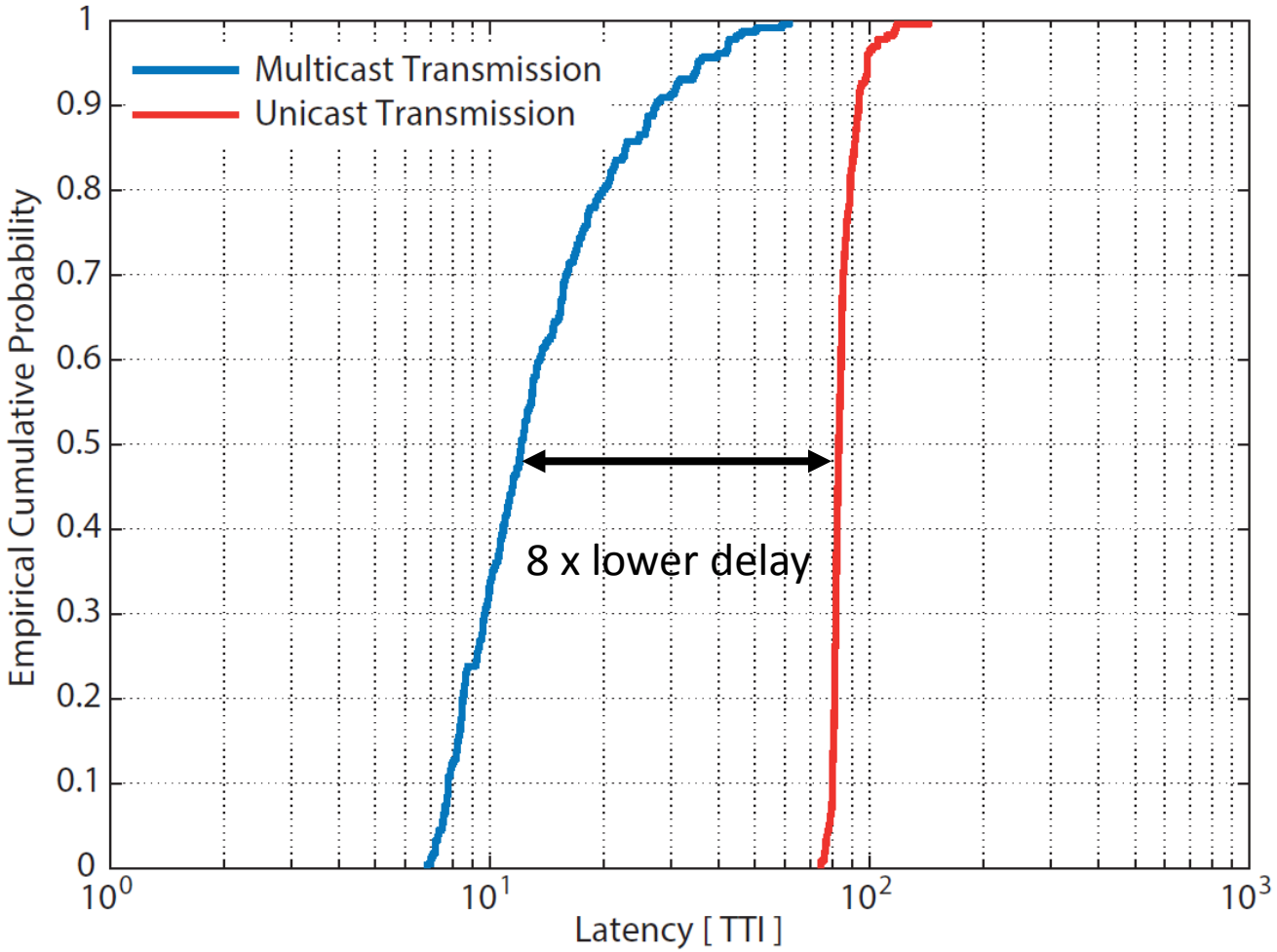
CAM: Cooperative Awareness Messages

- 7 cars per cell, 3 cells
- Every car sends message to every other
- 3 background users to obtain remaining resources

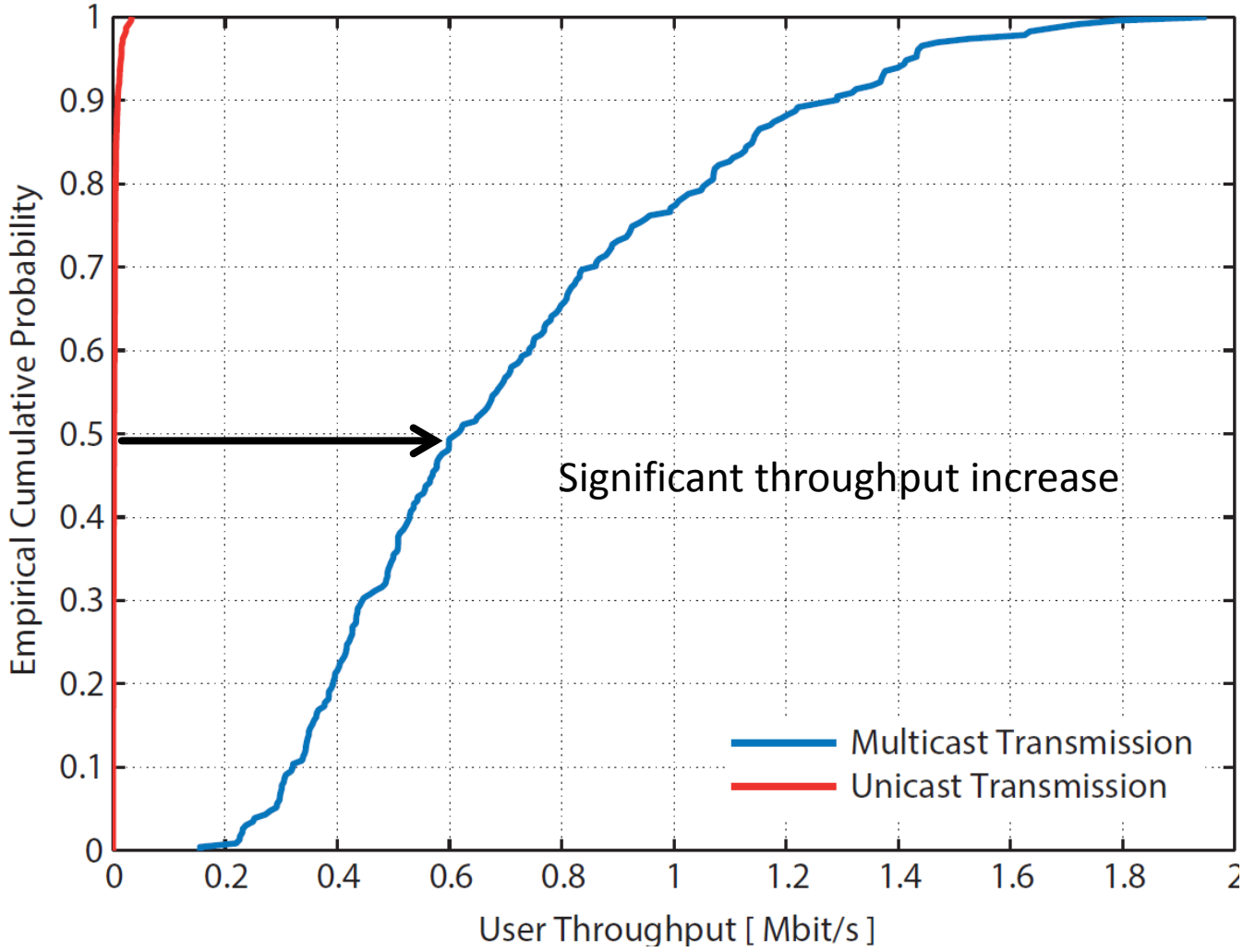


- What is better?
- Unicast or Multicast?

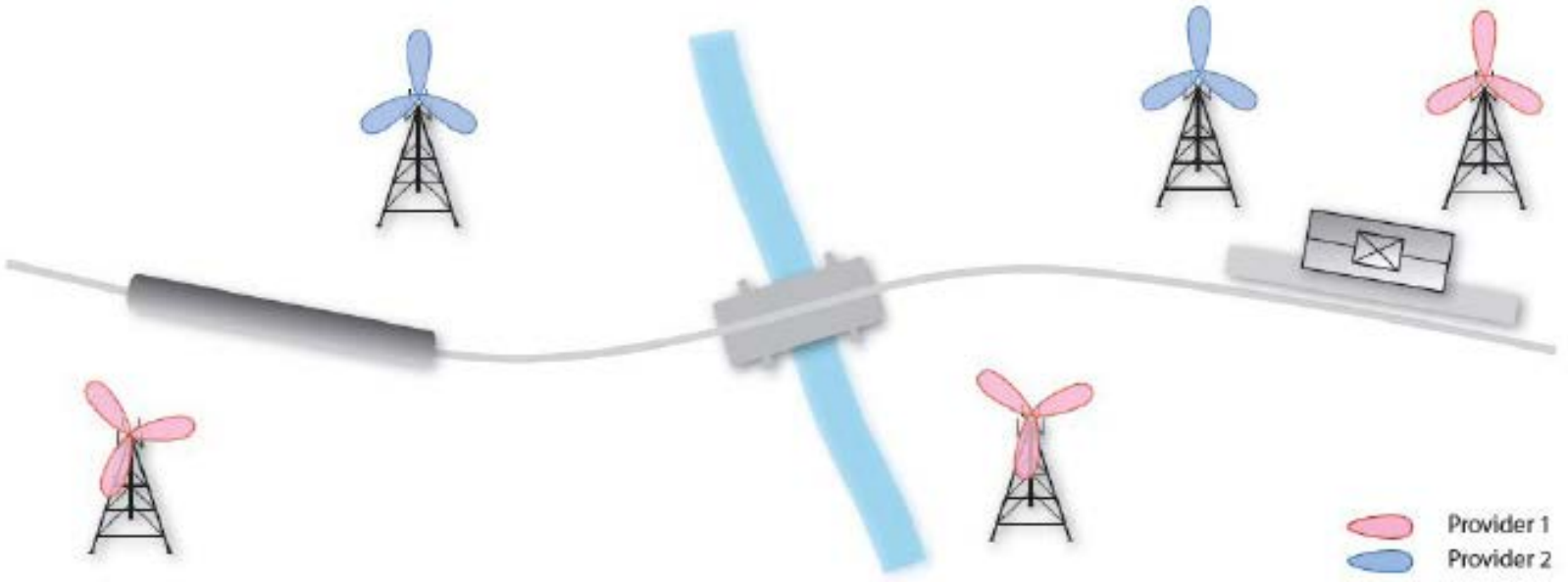
Latency


Multicast Transmission
Unicast Transmission
8 x lower delay
Empirical Cumulative Probability
Latency [TTI]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
10^0
10^1
10^2
10^3

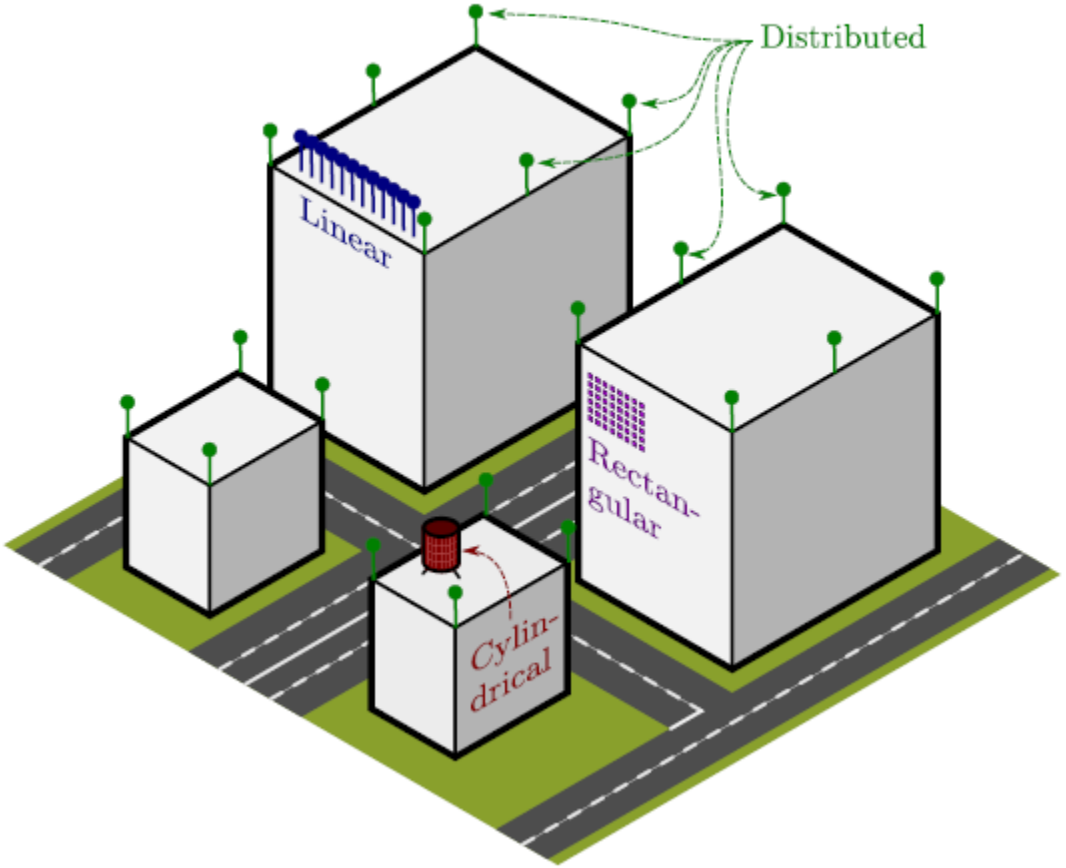
Throughput
of background users



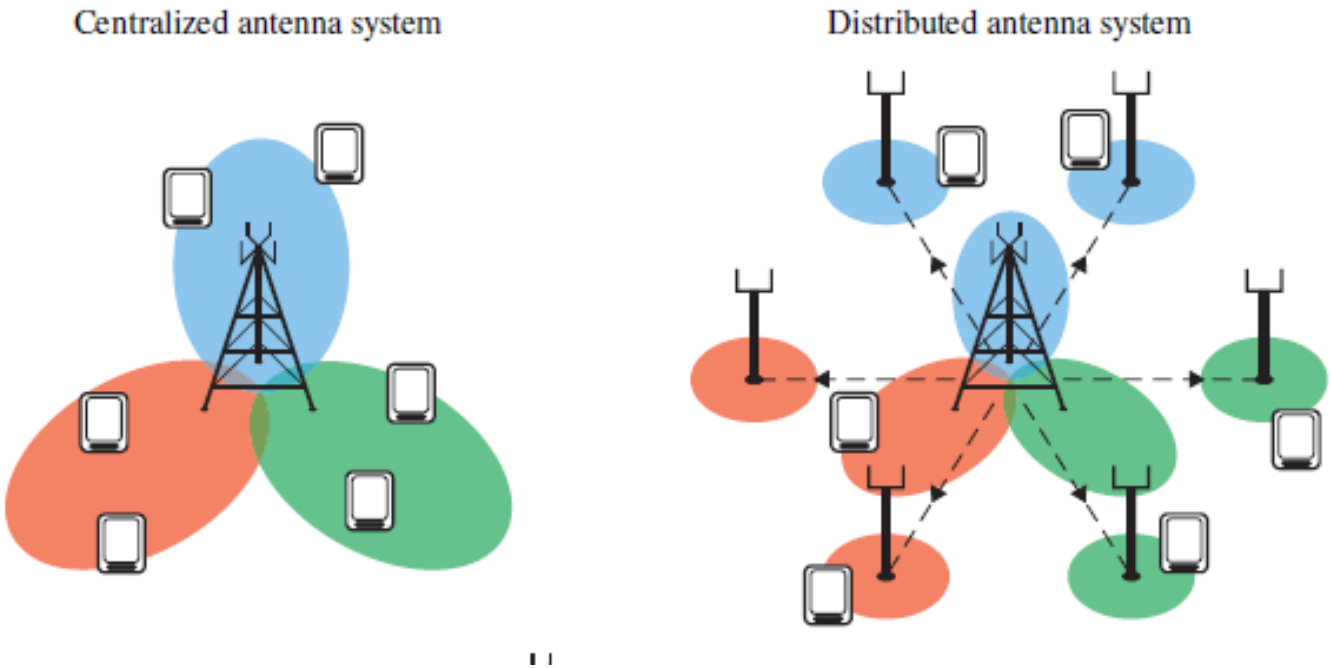
Distributed Antennas



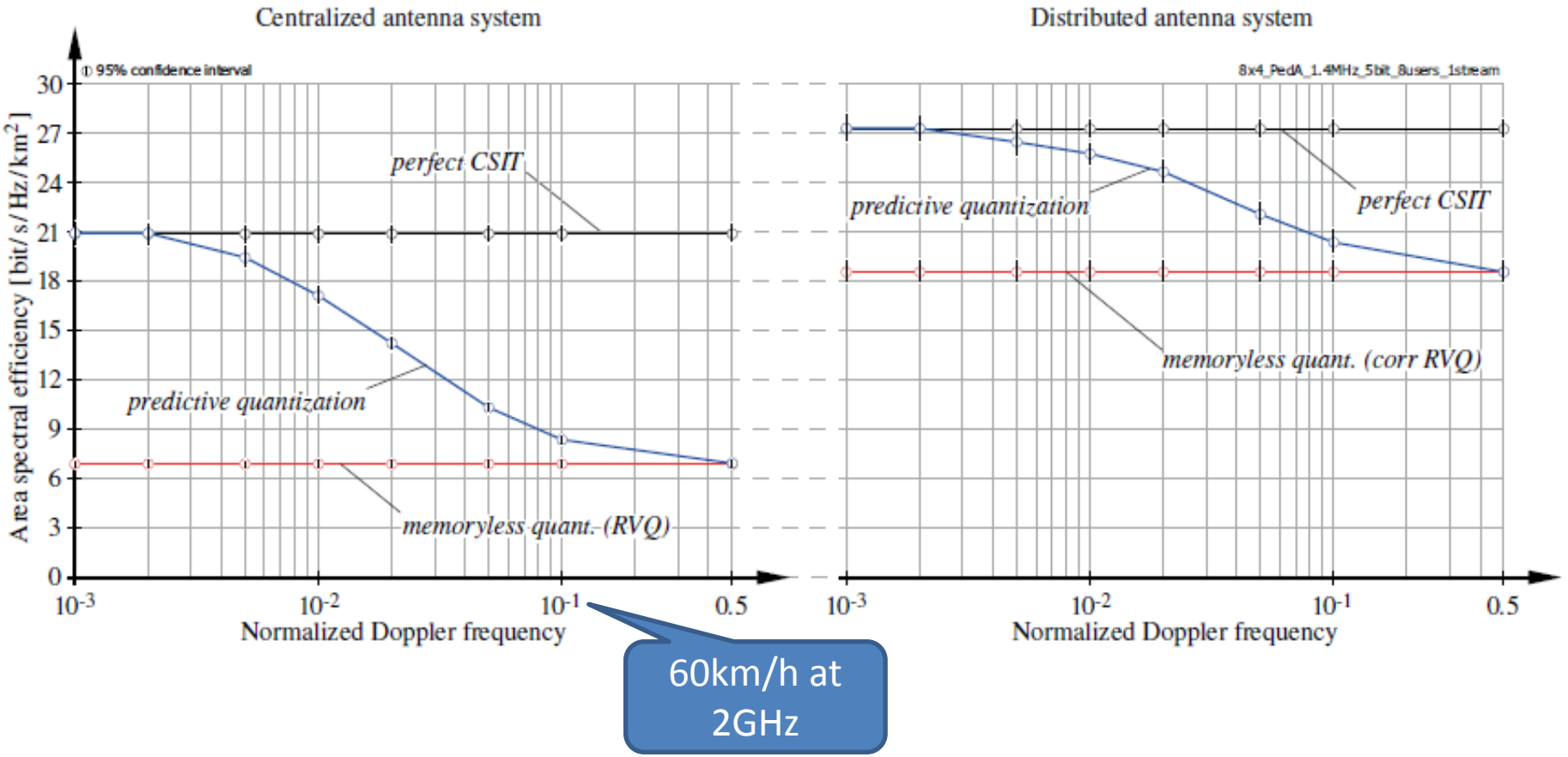
Future Deployment



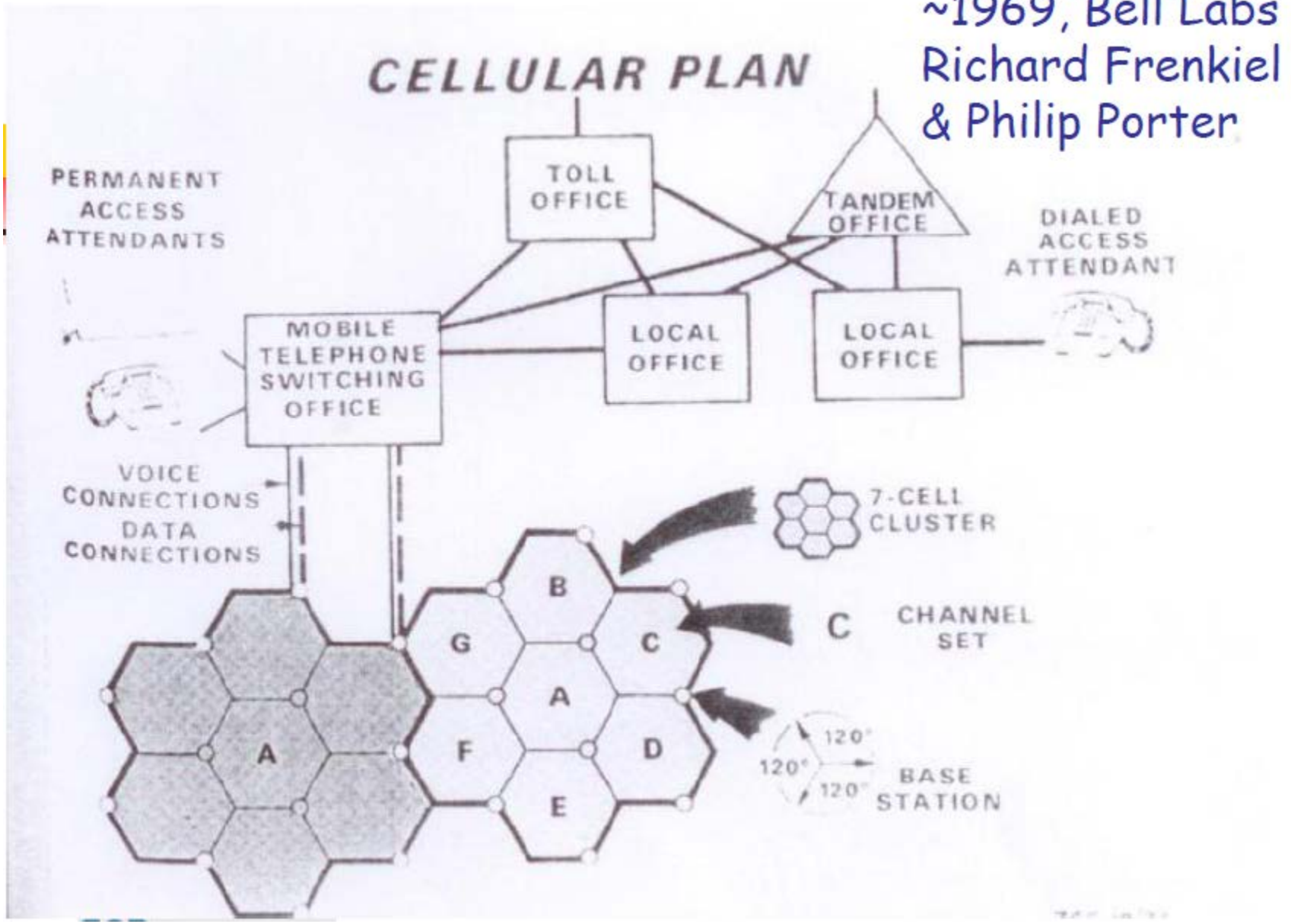
Compare centralized vs distributed antenna system



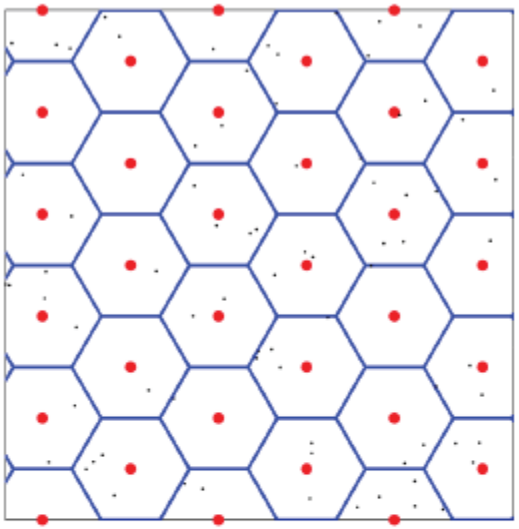
8x4 Antennas, 8 Users, 1 stream (ZF)

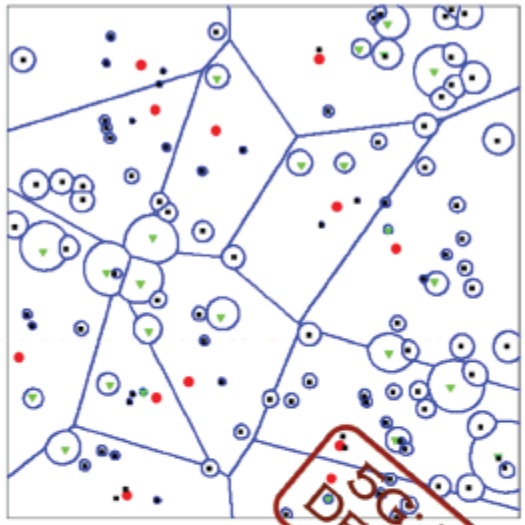


~1969, Bell Labs
Richard Frenkiel
& Philip Porter



Paradigm Change: ~2010



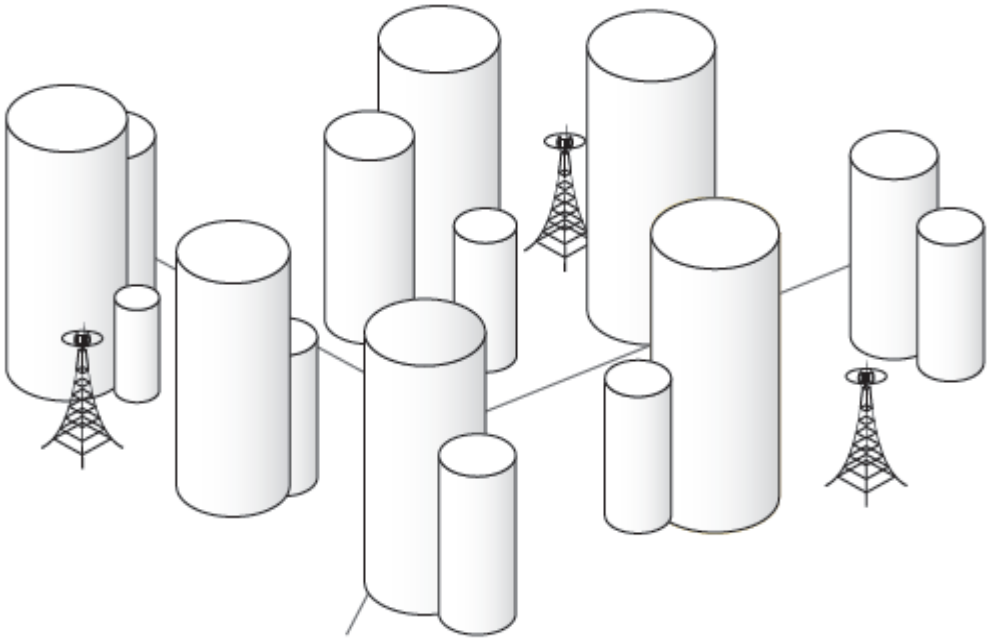


5G: EXTREME DENSIFICATION

- HetNets: macrocells, microcells, picocells, femtocells...
- CoMP
- Separate uplink/downlink routes
- Direct D2D

Urban Environment

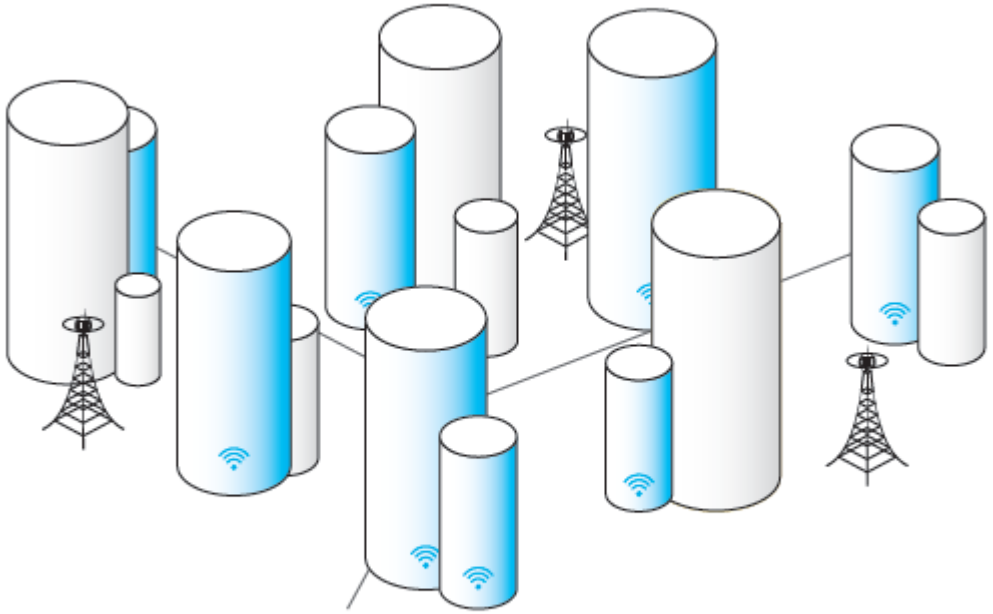
is not a flat plane



... but is rather characterized by building blockage ...

or so called indoor coverage ratio

Urban Environment



... with outdoor macro BSs and indoor small cells

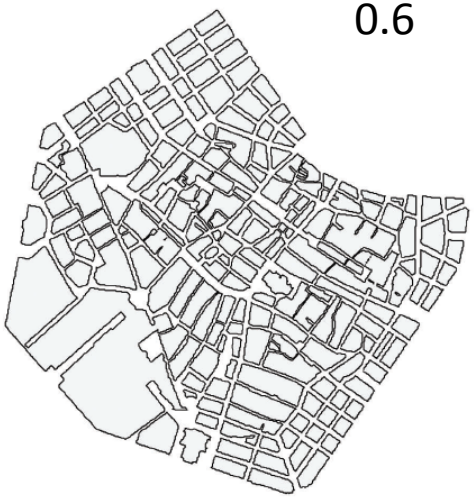
- We call this a 2-tier network **or so called small cell occupation**
- HetNet= Heterogenous Network

HetNets in Urban Environments

- Mayor influencial factors are
  - Small cell occupation probability η
  - Wall penetration loss L_W
  - Indoor coverage ratio

0.25

(a) University of Texas at Austin

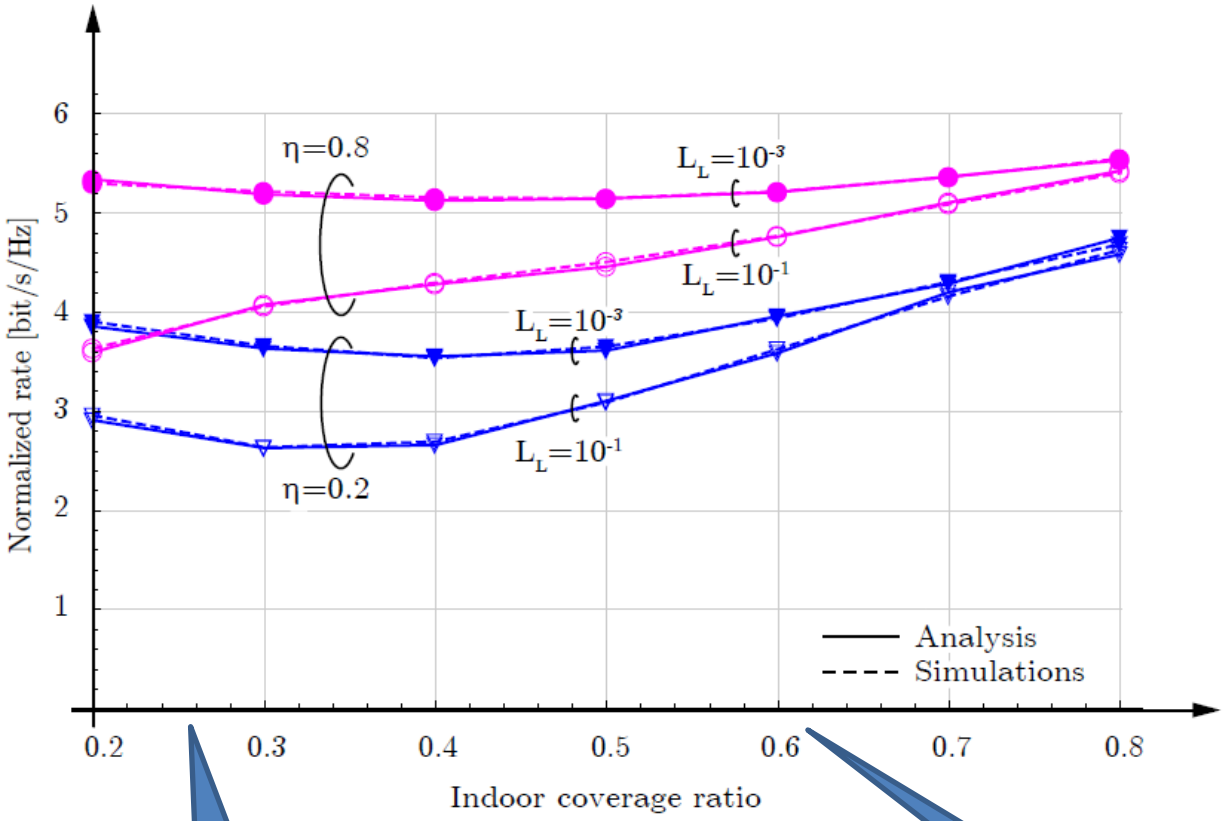


0.6

(b) Downtown Vienna

HetNets in Urban Environments

- Precise prediction by modelling:



Austin

Vienna

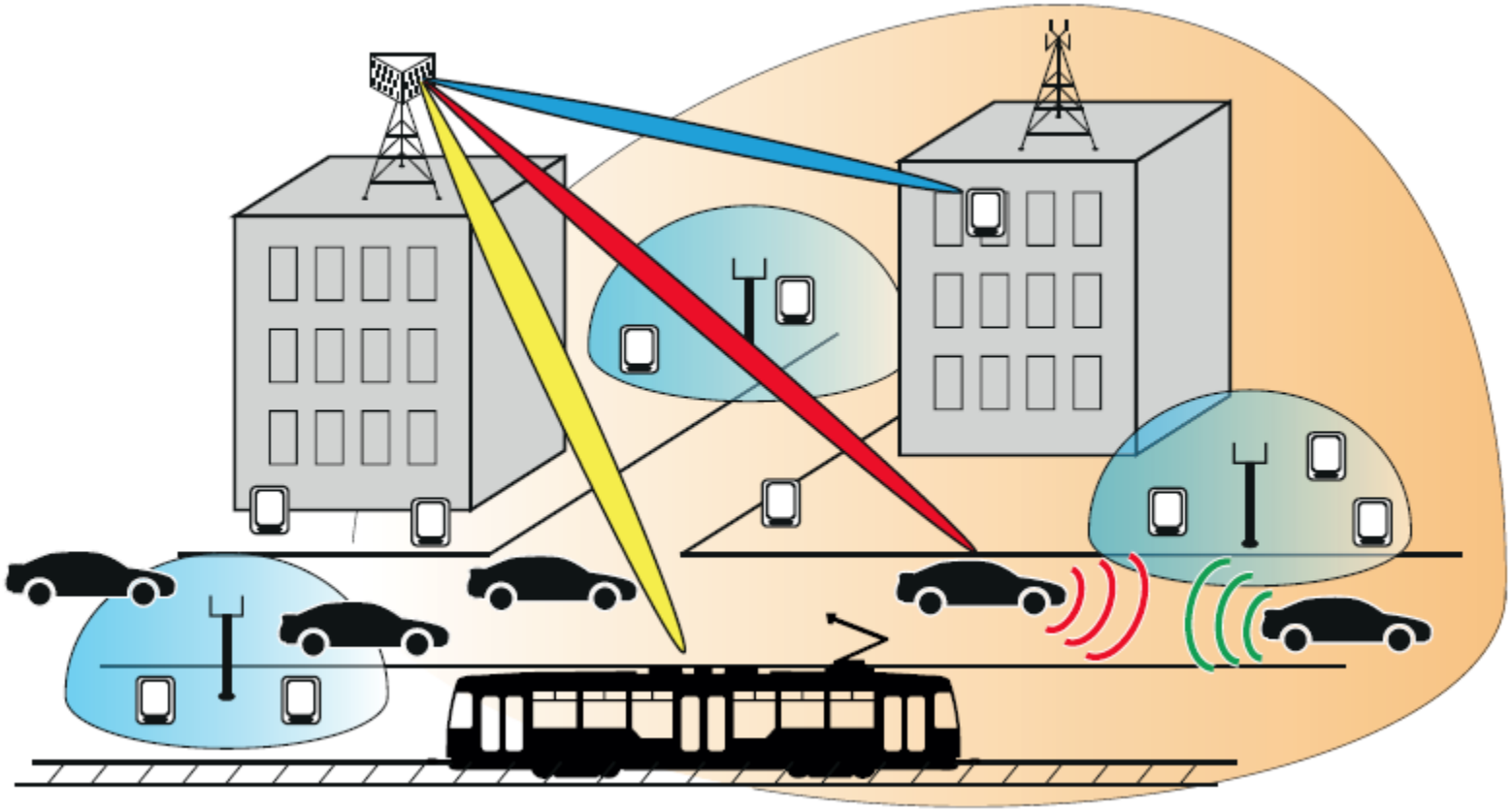
HetNets

- But not only static buildings can host their own small cells
- All traffic vehicles can do that
  - Trains, trams, cars, …
- They do not only need to provide traffic to their inside passengers but can work as moving small cells extending the network where infrastructure does not reach!

Conclusions

- Let us take a view on some 5G concepts:
- **mmWaves** work for short distances only
  - Fantastic for indoor coverage
  - No use in high mobile scenarios
- **Massive MIMO** requires static channel scenarios taking advantage of channel reciprocity
  - No use in high mobile scenarios

Massive Antenna Arrays



Massive Antenna Arrays

- Future cities will look like this?

Massive Antenna Arrays

- Alcatel Lucent (2013) 128 elements

- Bell Labs 1999

circular

Conclusions

- But modern concepts such as

- FBMC for high velocities
- Network densification by HetNets
- Distributed Antennas
- Broadcasting (eMBMS)

- Can really help and will be the future technology
- Just contact me: mrupp@nt.tuwien.ac.at

IWSLS² 2016

Institute of telecommunications

1st International Workshop on Link- and System Level Simulations

VLS

Powered by: Vienna LTE Simulator

The **1st International Workshop on Link- and System Level Simulations**, IWSLS² 2016, will take place in the city of **Vienna, Austria on July 1, 2016** and will be hosted by the **Institute of Telecommunications** (ITC) at the TU Wien (http://www.nt.tuwien.ac.at/).

IWSLS² (http://www.iwsls2.com/) is an international conference on theoretical, experimental, and applied research on link- and system level simulations of cellular wireless communication networks. IWSLS² brings together researchers and developers from both academia and industry to report on the latest scientific and theoretical advances, to debate major issues and to demonstrate state of-the-art systems. The proceedings of IWSLS² 2016 will be published in IEEE Xplore. More details can be found on http://www.iwsls2.com/.

Modus Operandi of the Conference

All papers will undergo a peer review and only those with a suitable innovation character will be selected. The presentation at the conference will be remotely; all accepted paper authors have to submit a presentation of their paper that will be offered at the web page of the conference and be connected with an online forum for further questions. It will be mandatory for the authors to provide feedback on the questions asked. Every author is also warmly invited to join us in Vienna for the presentation session. Through this, the **participation** of authors will be **free of charge**!

You do not even have to travel to Vienna!

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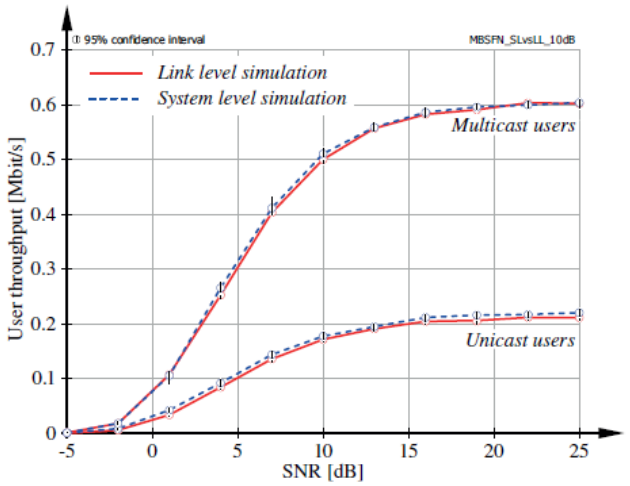
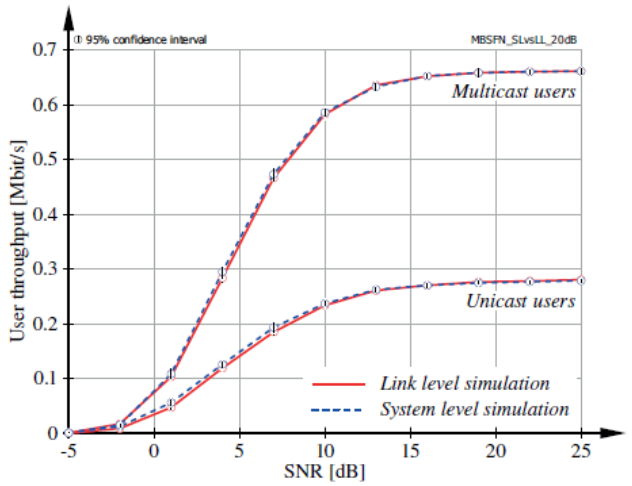
Backup

Some results

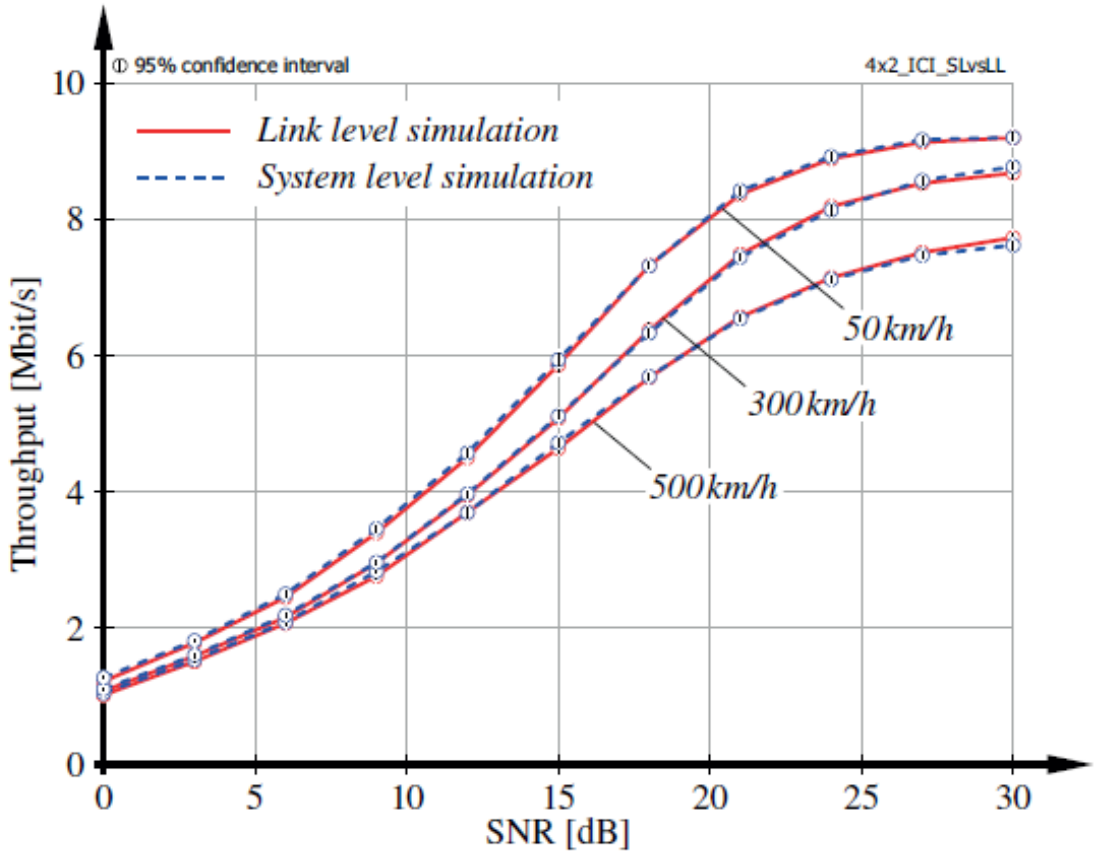
Parameter	Value
Frequency	2.14 GHz
LTE bandwidth	$B = 5$ MHz
Macroscopic path loss model	fixed
Shadow fading	none
Channel model	ITU-R Vehicular-A, block fading
Receiver type	zero forcing
Average noise power	−13 dB
Transmission rate	fixed, 1.2 bit per channel use (CQI 6)
Scheduler	round robin multicast group scheduler
Cyclic prefix	extended
Simulation length in TTI	$N_{\mathrm{TTI}} = 10\,000$



(a) Signal to interference ratio 10 dB.



(b) Signal to interference ratio 20 dB.


95% confidence interval
4x2_ICI_SLvsLL
Link level simulation
System level simulation
50km/h
300km/h
500km/h
Throughput [Mbit/s]
SNR [dB]
0
2
4
6
8
10
0
5
10
15
20
25
30