Statistical Modeling of Spatial Traffic Distribution with Adjustable Heterogeneity and BS-Correlation in Wireless Cellular Networks

Meisam Mirahsan
Rainer Schoenen
Halim Yanikomeroglu

Department of Systems & Computer Engineering
Carleton University
Ottawa, Canada

This work is supported in part by Huawei Canada Co., Ltd., and in part by the Ontario Ministry of Economic Development and Innovations ORF-RE (Ontario Research Fund - Research Excellence) program.

Carleton University

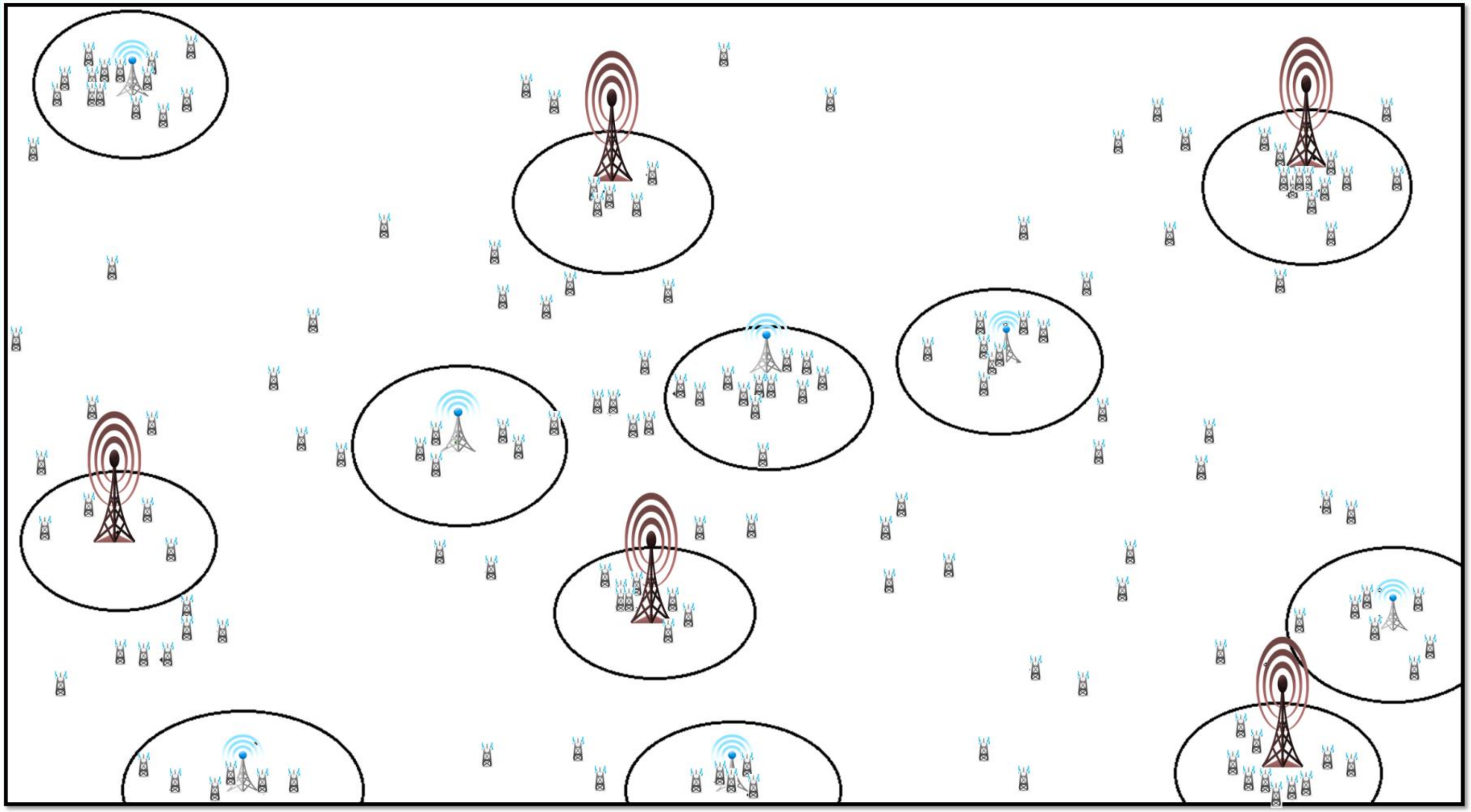
Agenda

- Introduction and Problem Statement
- Novelties and Contributions
- Modeling Procedure
- Traffic Measurement
  - Traffic Metrics
  - Traffic Statistics
- Traffic Generation
- Simulation Results

Introduction

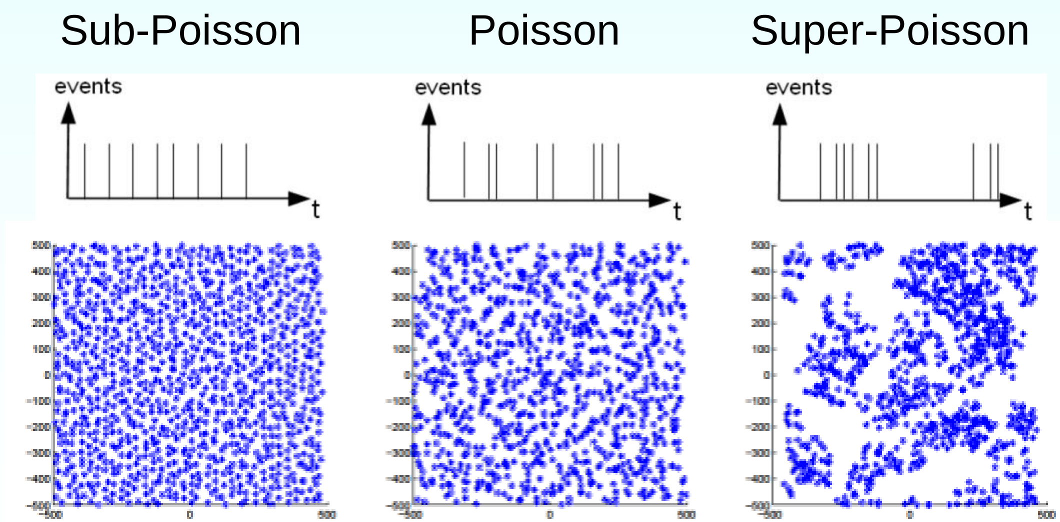
- Wireless traffic intensity is increasing
- Mean and heterogeneity
  - New applications
  - Time domain as well as space domain
- Performance analysis depends on realistic traffic models
  - Time domain: well investigated
    - PPP
    - Super-Poisson models: MMPP, HMM
  - Space domain: mainly PPP in the literature

Heterogeneous Infrastructure and Heterogeneous Traffic (HetHetNet)



Problem Statement

- The requirement: realistic and adjustable model:
  - Totally homogeneous to highly heterogeneous, and
  - BS-independent to completely BS-correlated

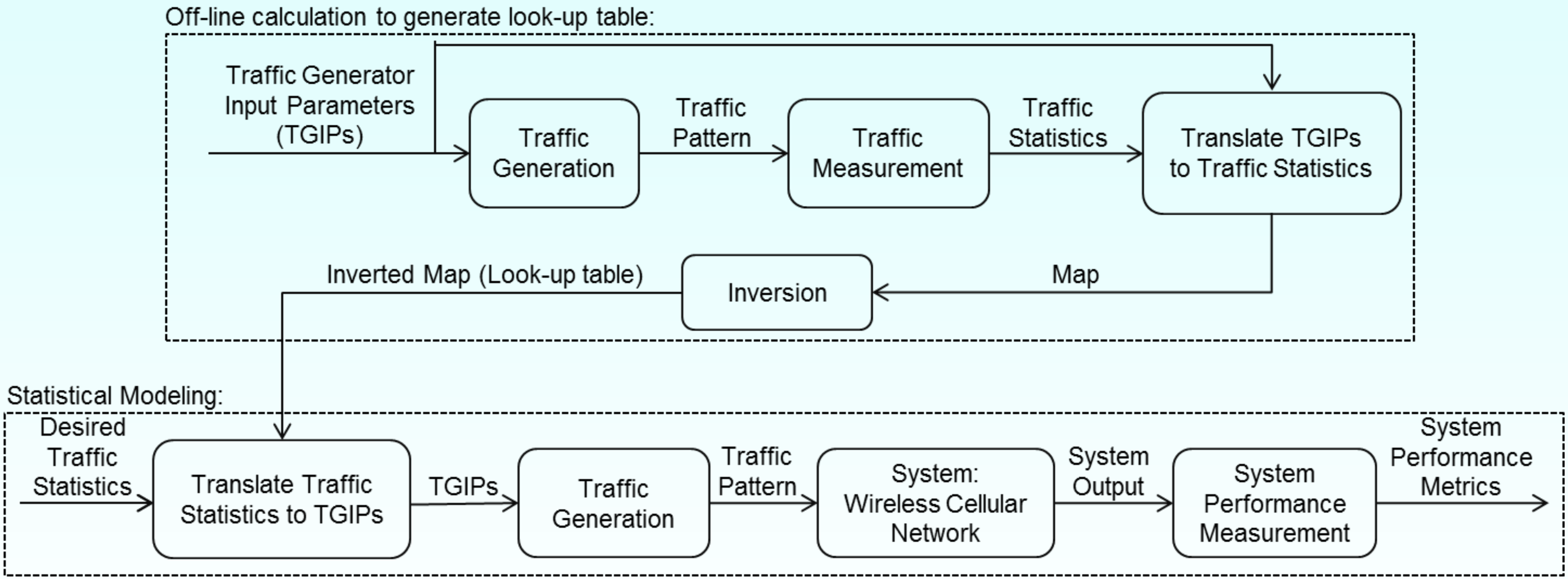


Novelties and Contributions

- Spatial traffic model with adjustable statistical properties with only two parameters:
  - the normalized second-moment statistic (CoV)
  - joint moment statistics with BSs

- The effects on the performance of wireless cellular networks

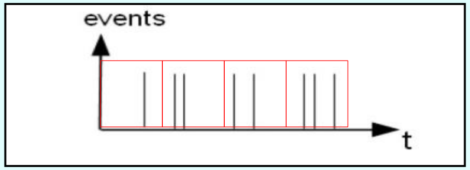
Modeling Procedure



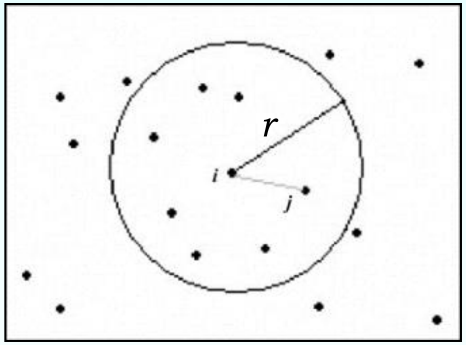
Carleton UNIVERSITY

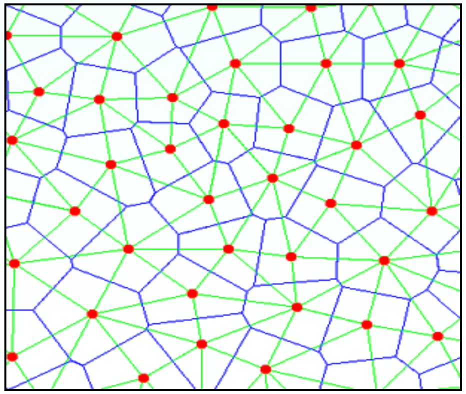
Traffic Measurement: Metrics

- Time domain:
  - Density based metrics: Interval counts
  - Distance based metrics: iat



- Space domain:
  - Density based metrics: Ripley's K
  - Distance based metrics: random tessellation metrics

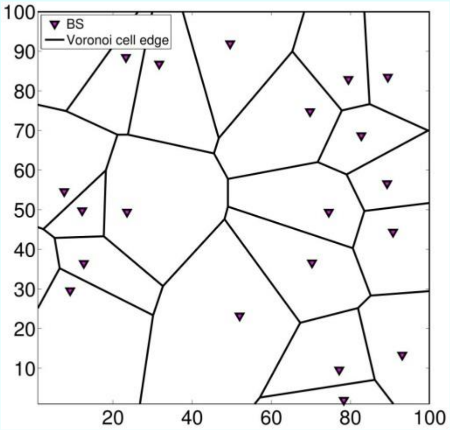


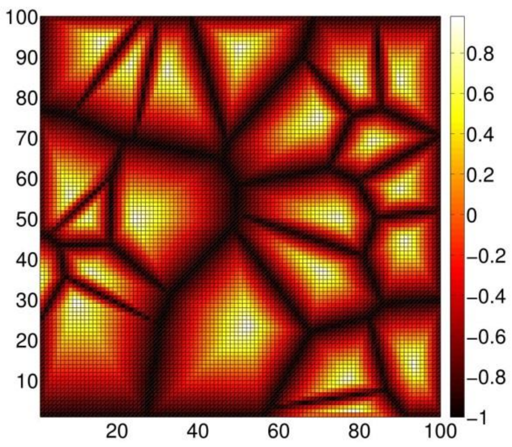


Traffic Measurement: Statistics

- Heterogeneity: coefficient of variation (CoV)
  - Std. normalized by the mean (std./mean)

- BS-correlation: correlation coefficient
  - $\rho = \frac{\sigma_{P\Lambda}}{\sigma_P \sigma_\Lambda}$
  - Potential function defined so that:
    - For point (x,y) at cell-center: $P(x,y) = +1$
    - For point (x,y) at cell-edge: $P(x,y) = -1$
    - For the entire cell: $\iint_{(x,y)\ in\ A} P(x,y) = 0$





Carleton UNIVERSITY

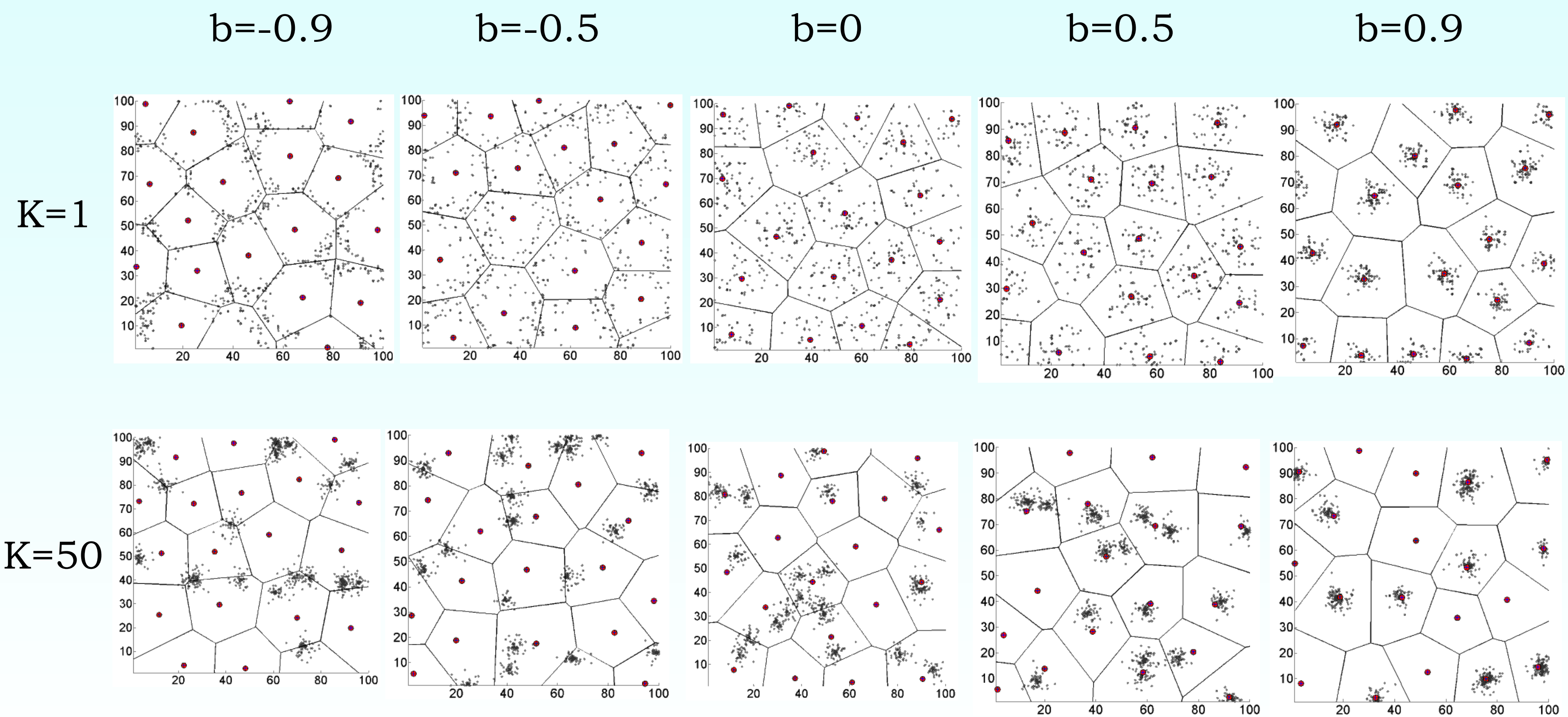
Traffic Generation

- Distribute the cluster-heads:

$$\Lambda_i(x, y, b) = \mu_{\Lambda} w_i(x, y, b)$$

- Generate K UEs around cluster-heads:
  - Uniformly in a ball centered at cluster-head

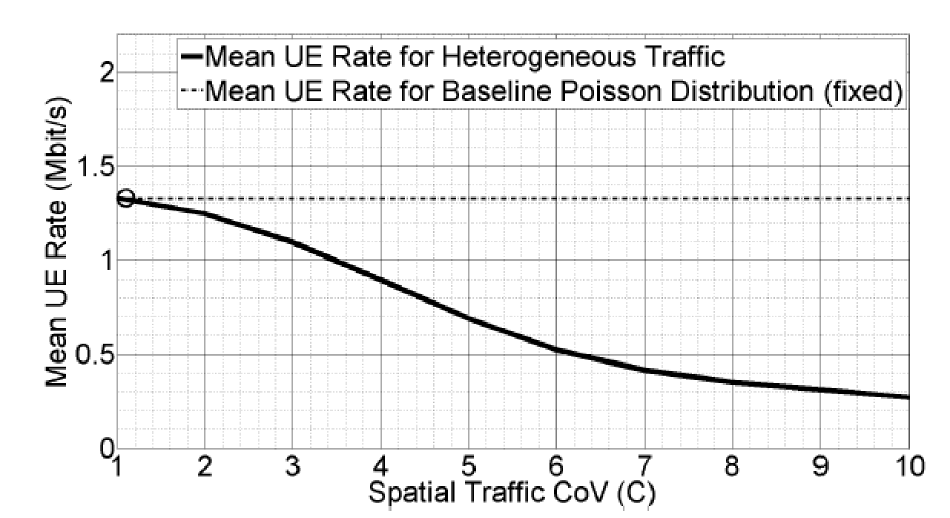
Sample Patterns

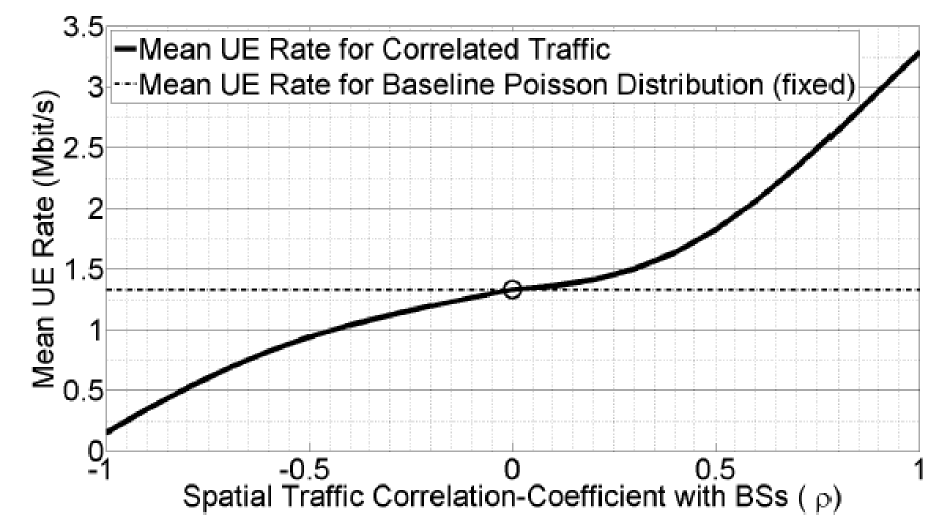


K: cluster size, K=1: Poisson

b: bias to BSs: b=0: Poisson, b=1: completely BS-correlated

Simulation Setup and Results

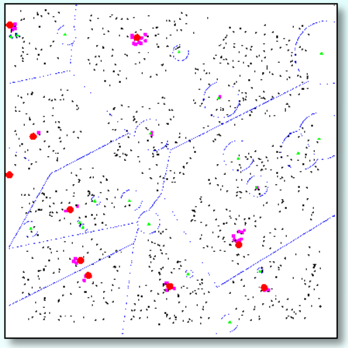




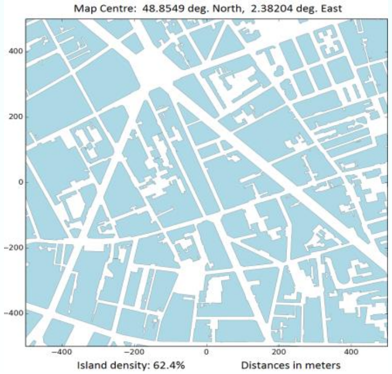
Parameter	Value
Carrier frequency	2 GHz
Bandwidth	20 MHz
Shadowing	Log-normal, std.= 4 for LOS, std.= 6 for NLOS
UE speed	30 km/h
Total BS Tx power	49 dBm
BS antenna height	25 m
Antenna number	SISO
Antenna model	Omni-directional
BS antenna gain	17 dBi
UE antenna gain	0
Traffic model	Full buffer
Number of drops	1000
Scheduling algorithm	Proportional Fair

Future Work

- **Application on HetNets (HetHetNet)**
  - Meisam Mirahsan, Rainer Schoenen, and Halim Yanikomeroglu, "HetHetNets: Heterogeneous Traffic Distribution in Heterogeneous Wireless Cellular Networks", under review in IEEE Journal on Selected Areas in Communications, Special Issue on Recent Advances in Heterogeneous Cellular Networks

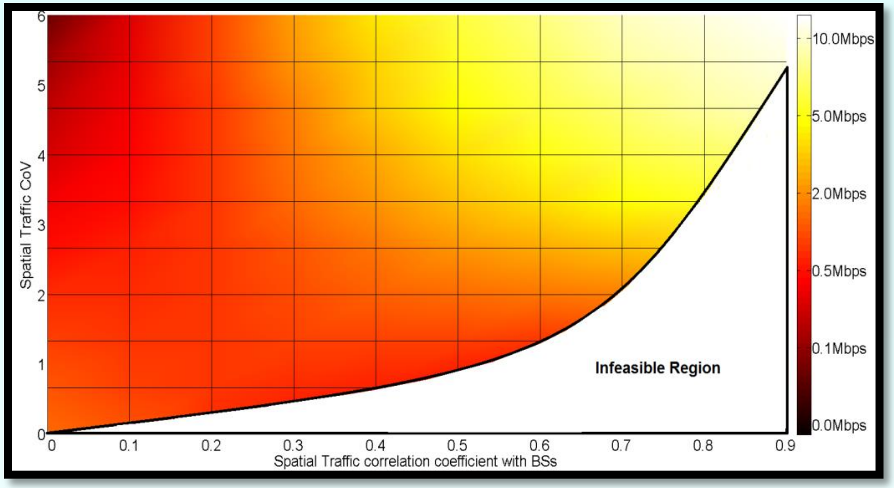


- **Real traffic measurements**
  - Meisam Mirahsan, Rainer Schoenen, Sebastian Szyszkowicz, and Halim Yanikomeroglu, "Spatial heterogeneity of users in wireless cellular networks based on open urban maps", submitted to IEEE International Conference on Communications (ICC) 2015, 8–12 June 2015, London, UK.

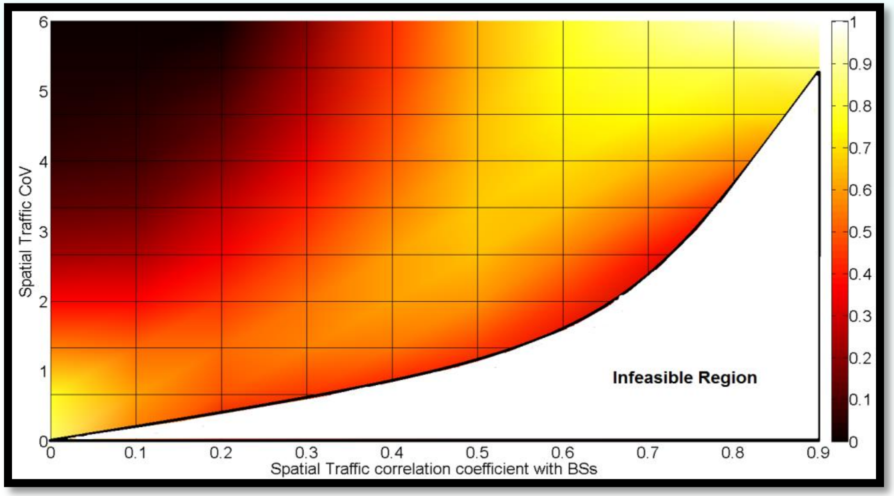


- **Combined time and space domain**

Simulation Results: Network Performance Metrics



Mean user rates



Coverage Probability

PARAMETER	VALUE
Mean number of UEs	1000
Number of Macro-BSs	10
Number of pico-BSs	20
Number of SAs	50
BSs distribution	PPP
BS antenna height	10 m
Number of drops	1000
Bandwidth (downlink)	20 MHz
Noise power per RB	-174 dBm/Hz
Carrier frequency	2.5 GHz
Total Macro-BS transmit power	37 dBm
Total pico-BS transmit power	17 dBm
Path loss and shaddowing	Based on UMi scenario [1]
BS antenna gain (boresight)	17 dBi
UE antenna gain	0 dBi
Time domain traffic model	Full buffer
Antenna model	Omni-directional
BS down tilt	12 degrees
UE antenna height	1.5 m
Shadowing model	log-normal with std: LoS: 3, NLoS: 6
Fading model	no fading
Scheduling	Proportional fair [43]

Thanks!