Technische Universität Braunschweig

Institute of Computer and Communication Network Engineering

Analysis of AAA Signaling Load in Mobile Environment

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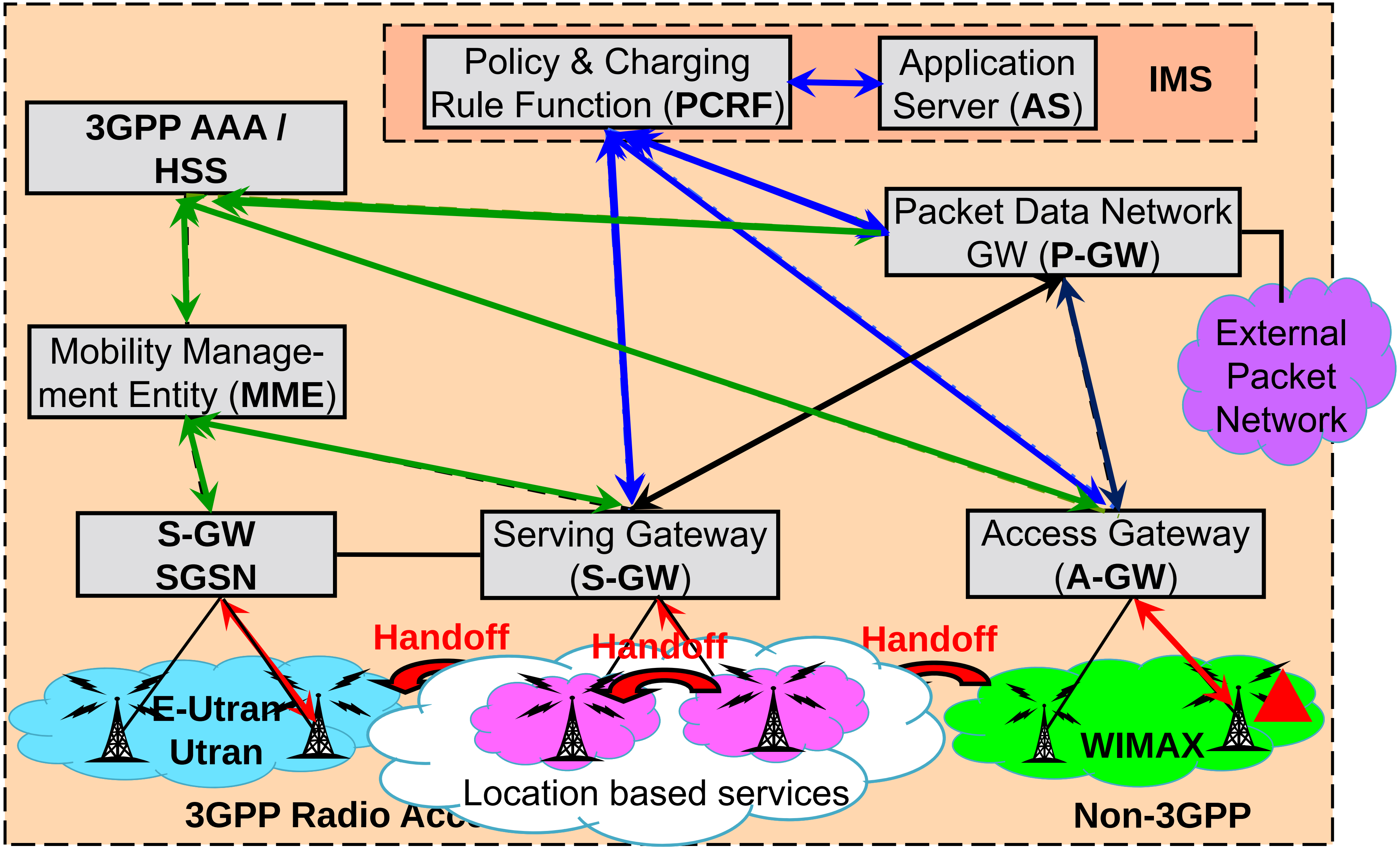
OUTLINE

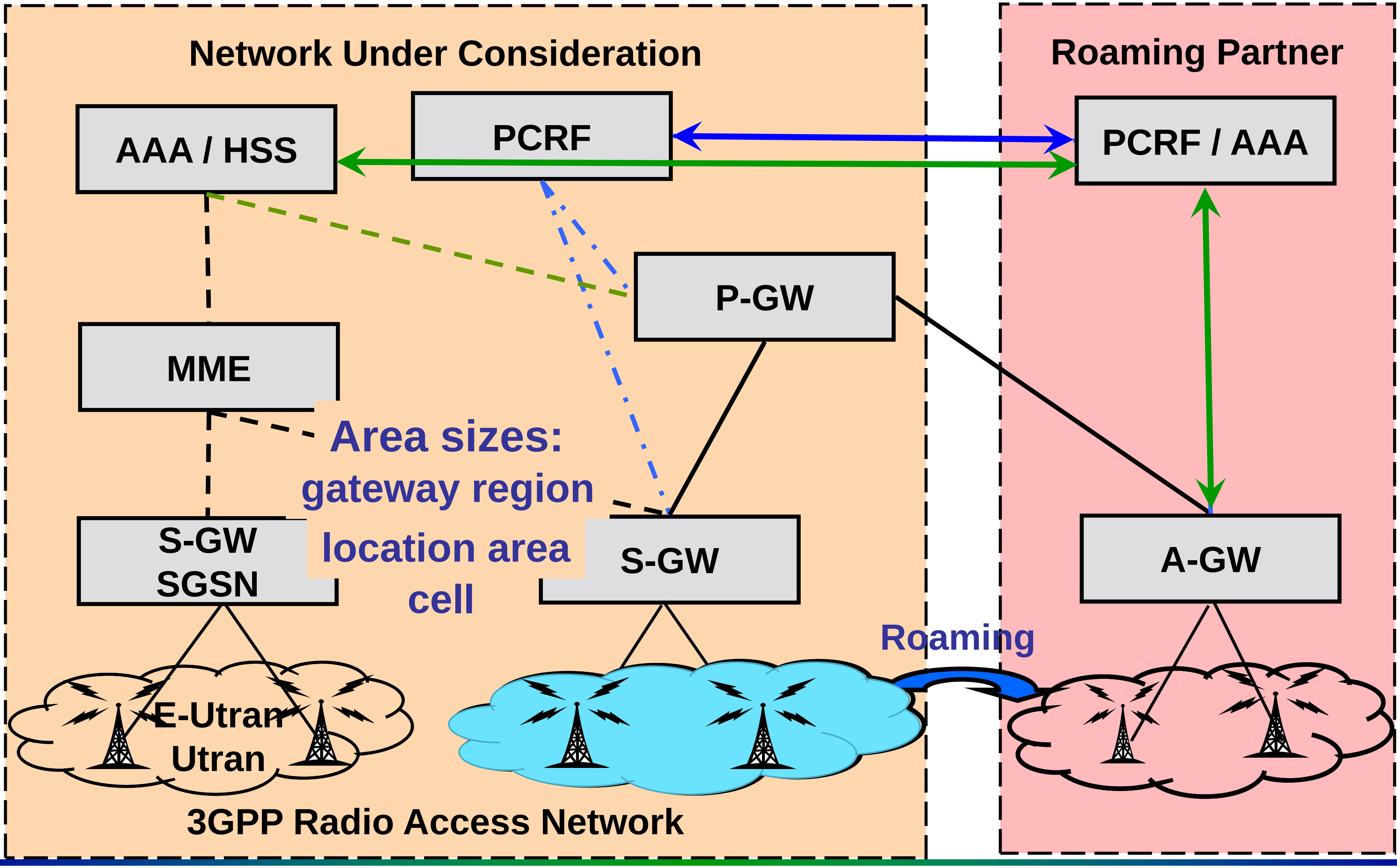
- Introduction
- Diameter Signaling Model
- Generalized Handoff Modeling
- Numerical results
- Conclusions

Core Network Architecture

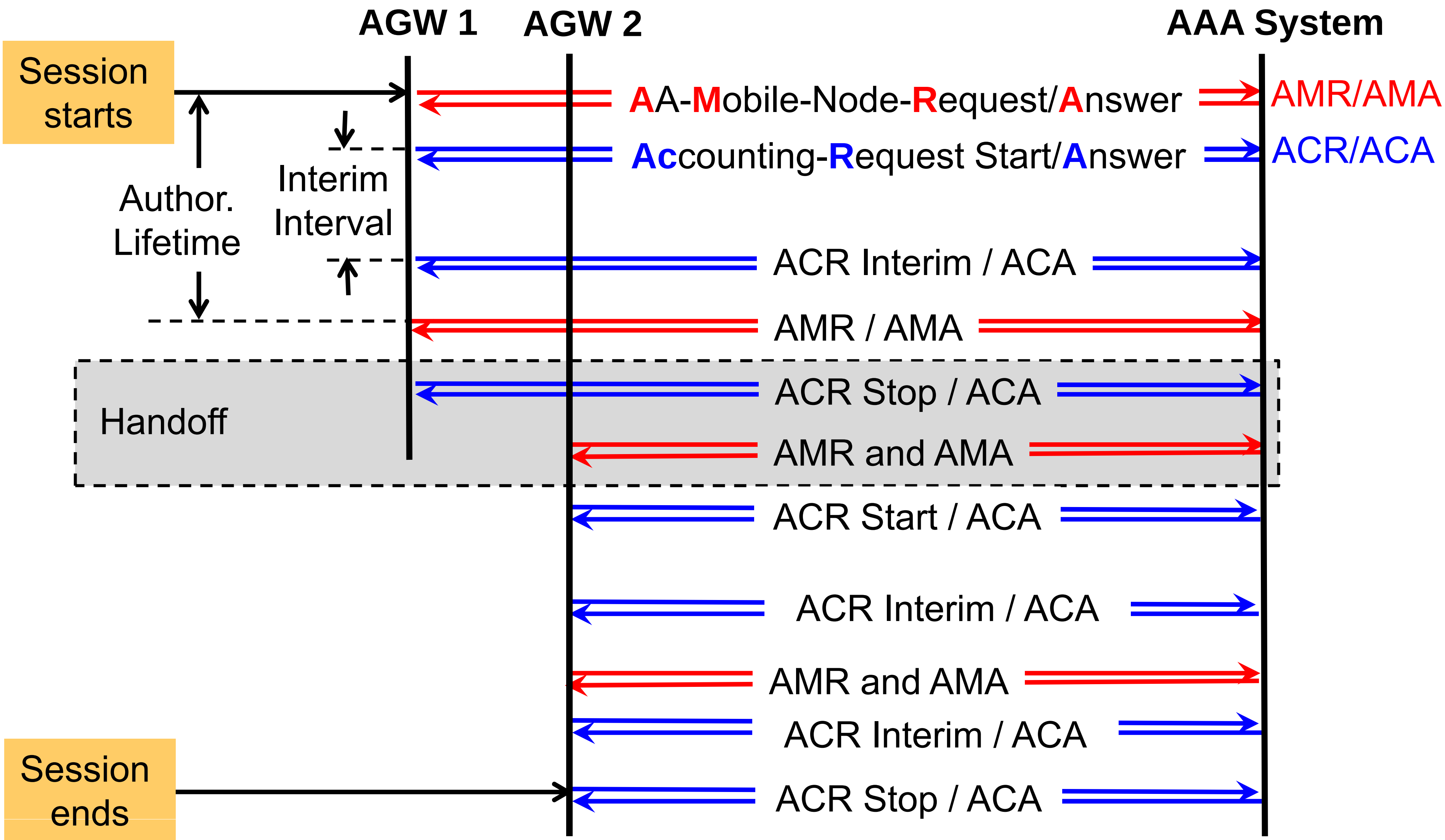


HSS: Home Subscriber System; IMS: IP Multimedia Subsystem

Core Network Architecture (2)



Application – Diameter Signaling for Postpaid Services-



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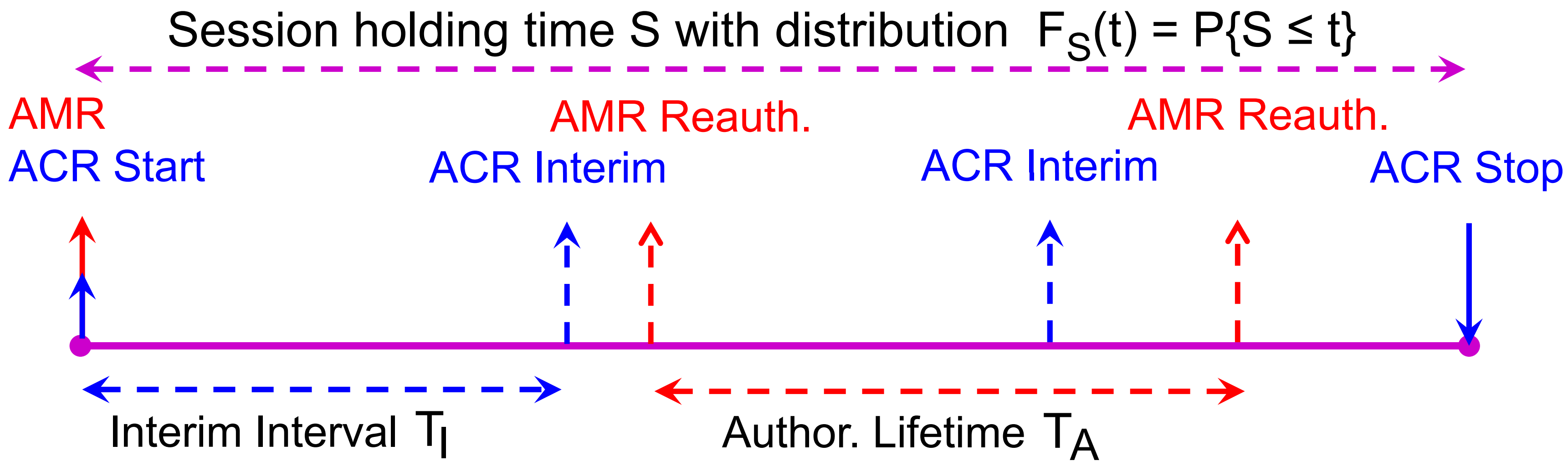
Signaling Rate Model in Fixed Environments



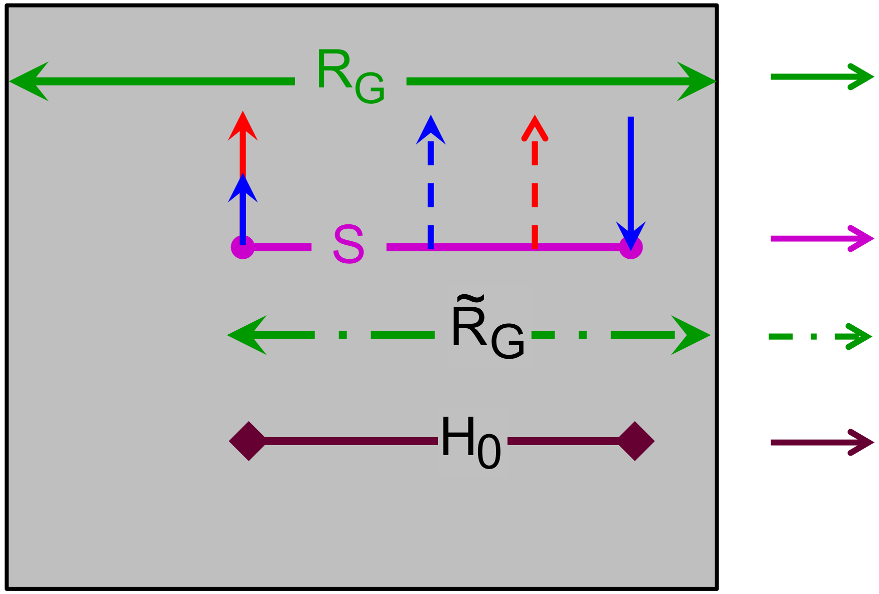
- Authentication success probability: p_A
- Expected number of AMR Reauth.: $E\{N|S,T_A\} = E\left\{\left\lfloor \frac{S}{T_A} \right\rfloor\right\}$

❖ Mean signaling rate per session:

$$E\{\xi\} = \underbrace{1_{AMR} + p_A \cdot E\{N|S,T_A\}}_{\text{Authentication}} + \underbrace{p_A\left(1_{start} + 1_{stop} + E\{N|S,T_I\}\right)}_{\text{Accounting}}$$

Signaling Rate Model in Mobile Environments

AGW serving area



AGW residence time
- Random time a user spends in a AGW area

Session holding time

Residual of AGW residence time

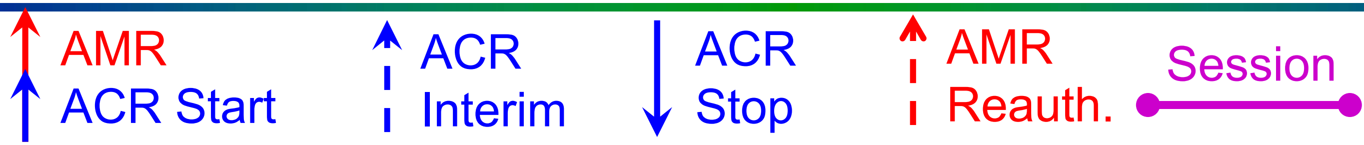
Channel holding time

$$F_{H_0}(t) = P\{H_0 \le t | S \le \tilde{R}_G\}$$

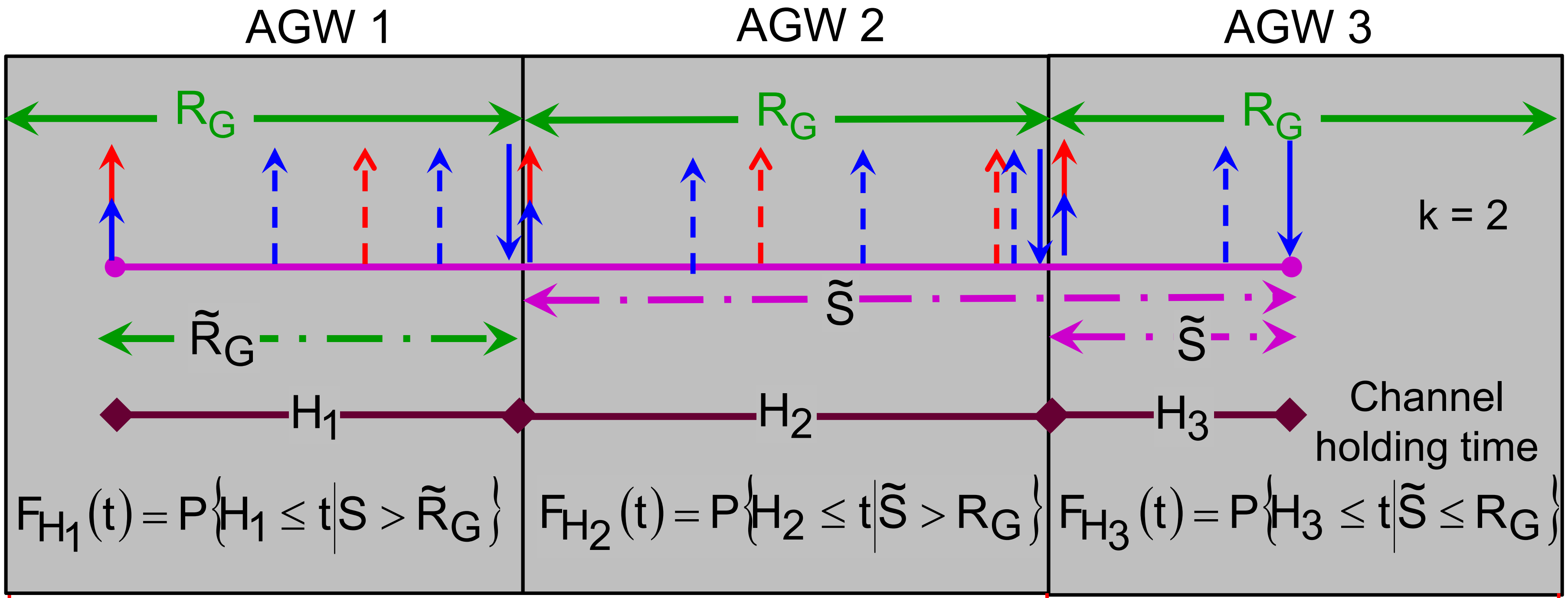
- Probability for k handoffs: $P_H(k)$, k = 0, 1, 2,….

❖ Mean number of signaling messages per session for zero handoffs (k = 0):

$$E\{\xi,0\} = P_H(0)\cdot\left(1_{AMR} + p_A\cdot\left[E\{N|H_0,T_A\} + 1_{start} + E\{N|H_0,T_I\} + 1_{stop}\right]\right)$$



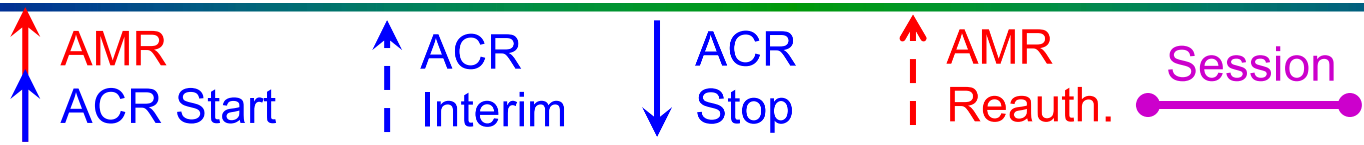
Signaling Rate Model – k Handoffs -



$$E\{\xi, k\} = P_H(k) \cdot ($$

$$(1_{AMR} + p_A \cdot [E\{N|H_1, T_A\} + (k-1)(1_{AMR} + E\{N|H_2, T_A\}) + 1_{AMR} + E\{N|H_3, T_A\} +$$

$$+ k \times 1_{start} + E\{N|H_1, T_I\} + (k-1) \times E\{N|H_2, T_I\} + E\{N|H_3, T_I\} + k \times 1_{stop}])$$



Mean Number of Signaling Messages

- Mean number of signaling messages per session

$$E\{\xi\} = \sum_{k=0}^{\infty} E\{\xi,k\} = 1_{AMR} + p_A \cdot \{1_{AMR} \cdot E_{HO} + E\{N_A\} + \\ + (1_{start} + 1_{stop})(1 + E_{HO}) + E\{N_I\}\}$$

depends on

- mean number off handoffs E_{HO}
- mean number of AMR-Reauth. $E\{N_A\}$ / ACR-Interim Messages $E\{N_I\}$
  - which are functions of
    - handoff statistics $P_H(k)$ and
    - channel holding time statistics $F_{Hi}(t)$, i = 0,1,2,3
    - protocol parameters T_A and T_I

Mean Signaling Rate at AAA System

- Assumptions
  - Poisson Arrival process of sessions to AGW i with rate λ_i
  - Exponentially distributed session holding times
  - Homogenous statistics for gateways and user mobility
    - iid residence times, user mobility and channel holding times
    - infinite size of the network

- Signaling rate at AAA system

$$E\{\Lambda\} = E\{\xi\} \cdot \sum_{i=0}^{N_{AGW}} \lambda_i$$

- Model generalization
  - **We need to determine the detailed handoff statistics**

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Markovian Modeling of User Mobility Pattern

- Area j^{th} border are labeled by the set $B_j = \{a, b, c, d, e\}$
- A Markovian mobility model is assumed:
  - A user entering area j is described by a set of transition probabilities p_{jxy}
  - They depend on the entry border $x \in B_j$ and the exit border $y \in B_j$
- Probabilities for transitions inside the network

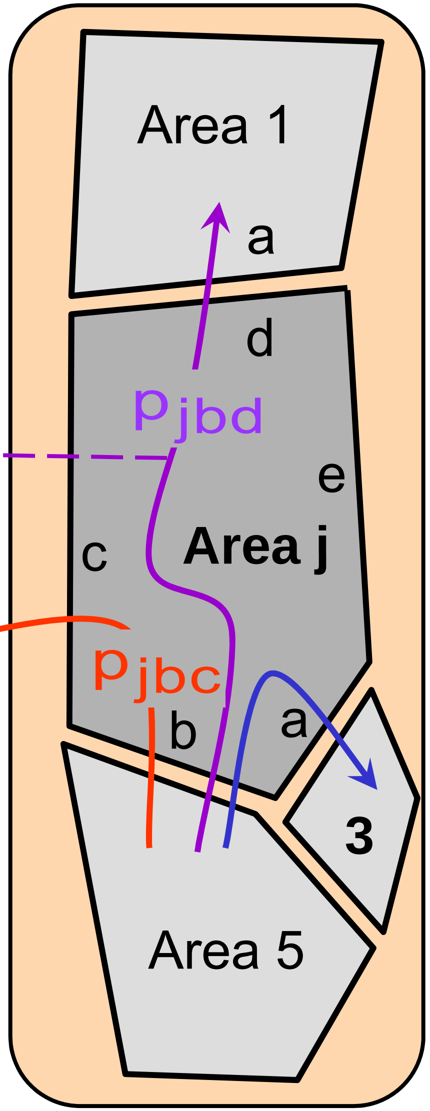
$$\mathbf{M}_N = \begin{pmatrix} \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & p_{jba} & \cdots & p_{jbd} & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{pmatrix}$$

Entry border b,
exit border d,
next entry border a

- Probabilities for transitions leaving the network

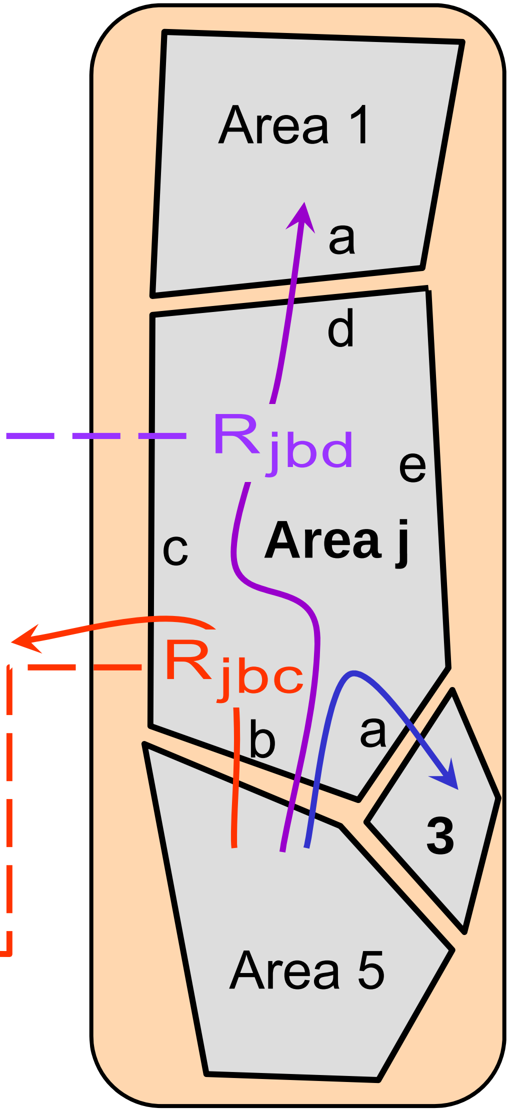
$$\mathbf{M}_A = \begin{pmatrix} \vdots \\ p_{jbc} \\ \vdots \end{pmatrix}$$

Entry border b, exit border c, **roaming**



Area Residence Time

- The residence time R_{jxy} is the generally distributed random time a user spends in an area j.
  - it depends on entry border x and exit border y
  - it is related to the movement pattern
  - its density has a Laplace transform $f^*_{R_{jxy}}(s)$
- Sequence of residence times
  - are allowed to be non-identically distributed
  - are assumed to be independent
- Matrix representation for their Laplace transforms
  - for transitions inside the network: $\mathbf{R}^*_{\mathbf{N}}(s)$
  - for transitions leaving the network: $\mathbf{R}^*_{\mathbf{A}}(s)$



Handoff Probability - Multiple Path Analysis -

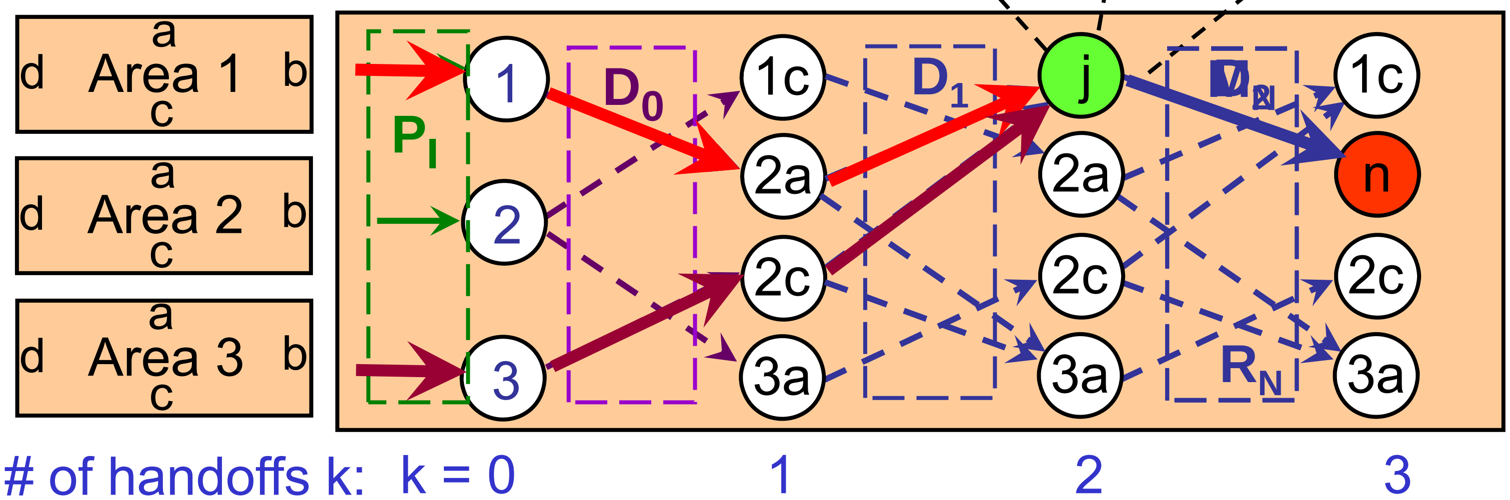
- Average path residence time to reach entry border 1c (state j): $R_{Dj}(k)$

- Handoff probability for sessions in state j after making k handoffs to make the next handoff to neighboring area's state n

$$P_{H(j,n)}(k+1) = \frac{P\{R_{Dj}(k) + R_{j,n} \le S\}}{P\{R_{Dj}(k) \le S\}}$$

- Transition probability for sessions in state j after making k handoffs

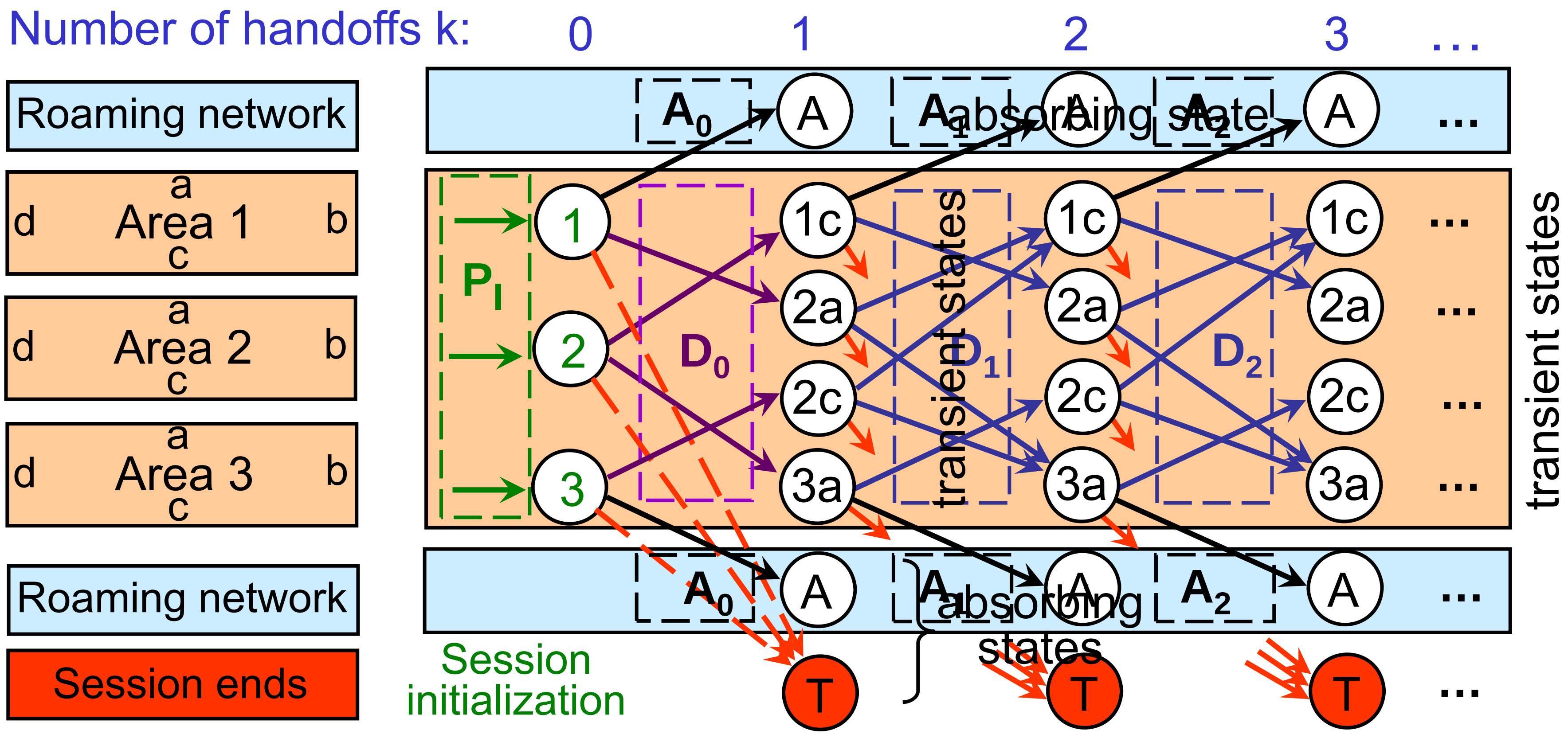
$$d_{j,n}(k) = m_{N(j,n)} \cdot P_{H(j,n)}(k+1)$$



- Model behaves like a discrete time non homogenous Markov chain

Network, Session, Mobility: A Transient Markov-Chain Approach

- Transient states are given by the area's entry borders
- Roaming networks (A) and session termination (T) are absorbing states
- Handoffs are discrete (time) steps in a transient Markov chain



Performance Measures

- Handoff probability for heterogeneous networks with limited size
- Mean number of handoffs (MNH) inside the network
  - MNH for mobiles entering an area through a specific border

Handoff rate
- per area
- per technology
- vertical / horizontal

- Roaming probability to a neighbor network

- Closed form matrix-analytical solution in form of a complex integral
- Closed form result in the time domain if the session time has a rational Laplace transform

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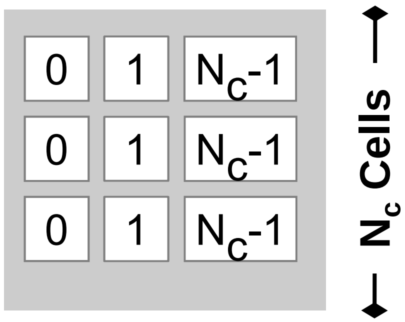
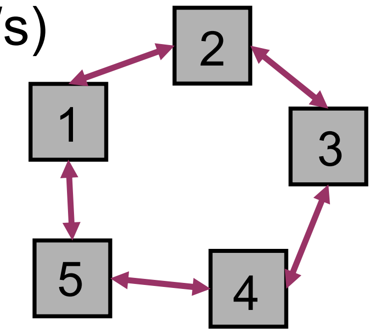
Diameter Signaling Rate

- AGW serving area
  - Square area of N_C x N_C cells
  - Lognormal distributed Cellular residence time

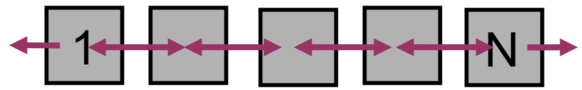


- AGW residence time R_G with mean E_R depends on:
  - Size of the AGW serving area
  - User mobility
    - uniform inter cell mobility
    - % of users starting in each area

- AGW topology
  - Infinite network size (ring of 5 AGWs)

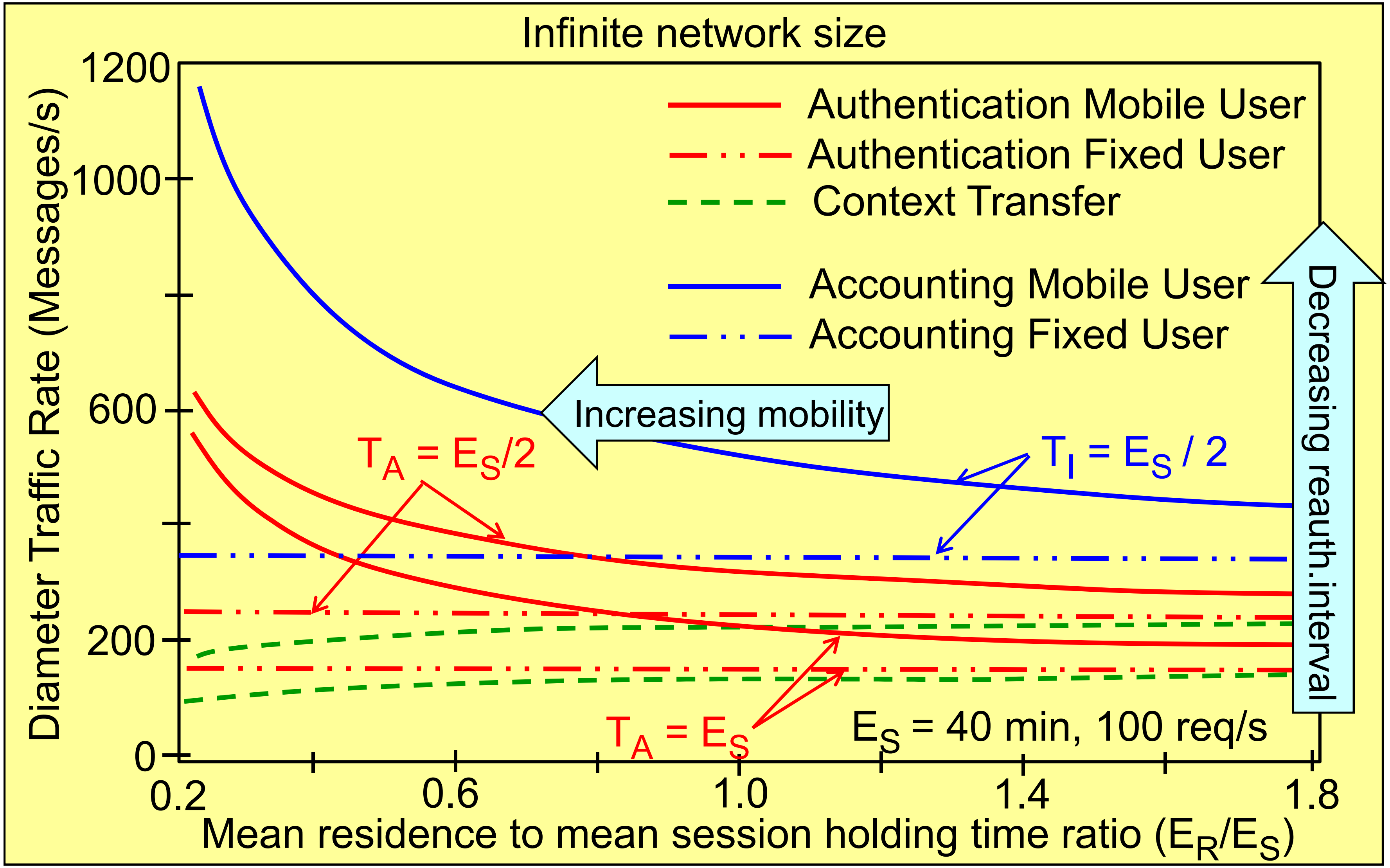


  - Finite network size with linear topology and roaming users

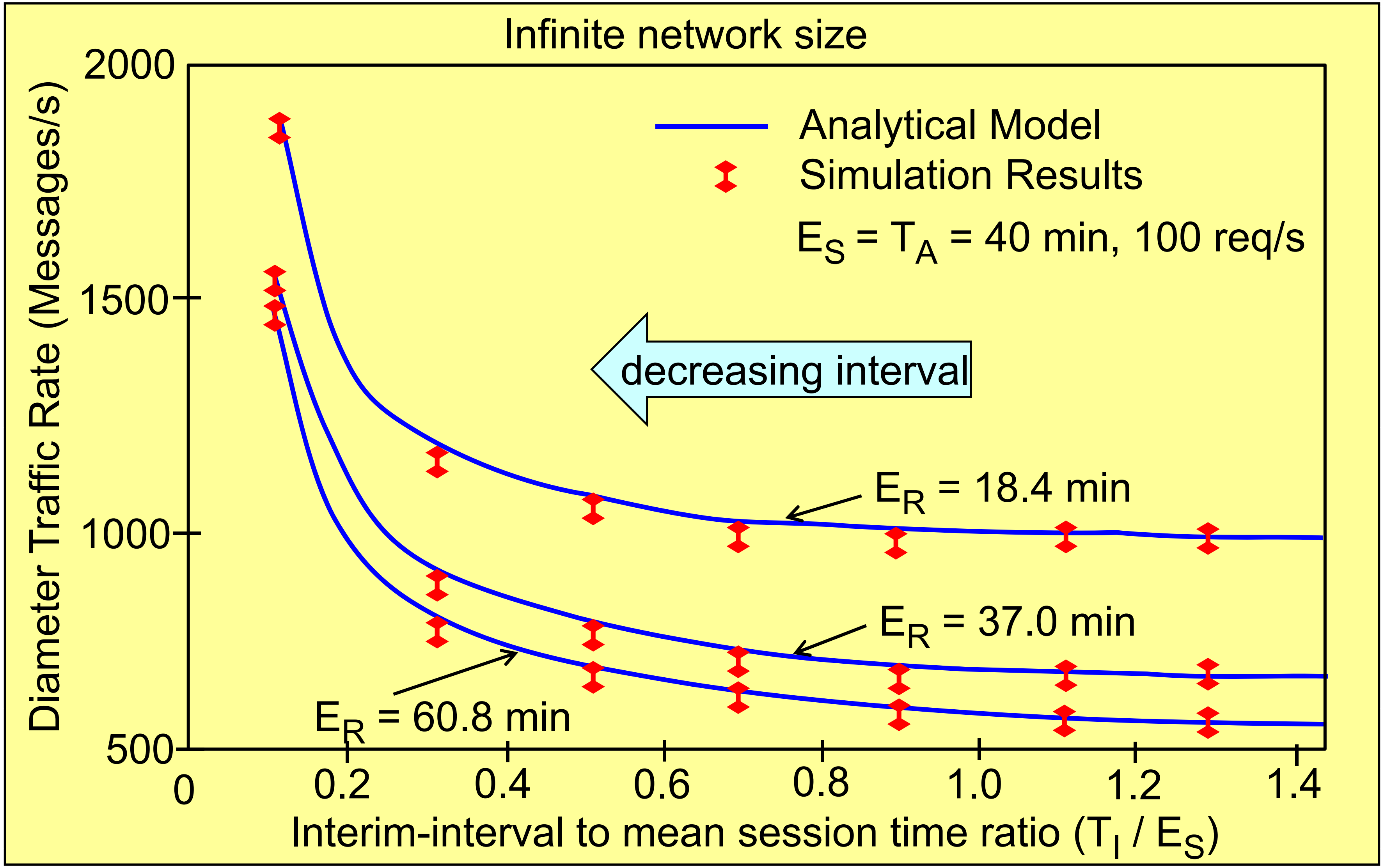


- Session holding time
  - Erlang distributed with mean E_S

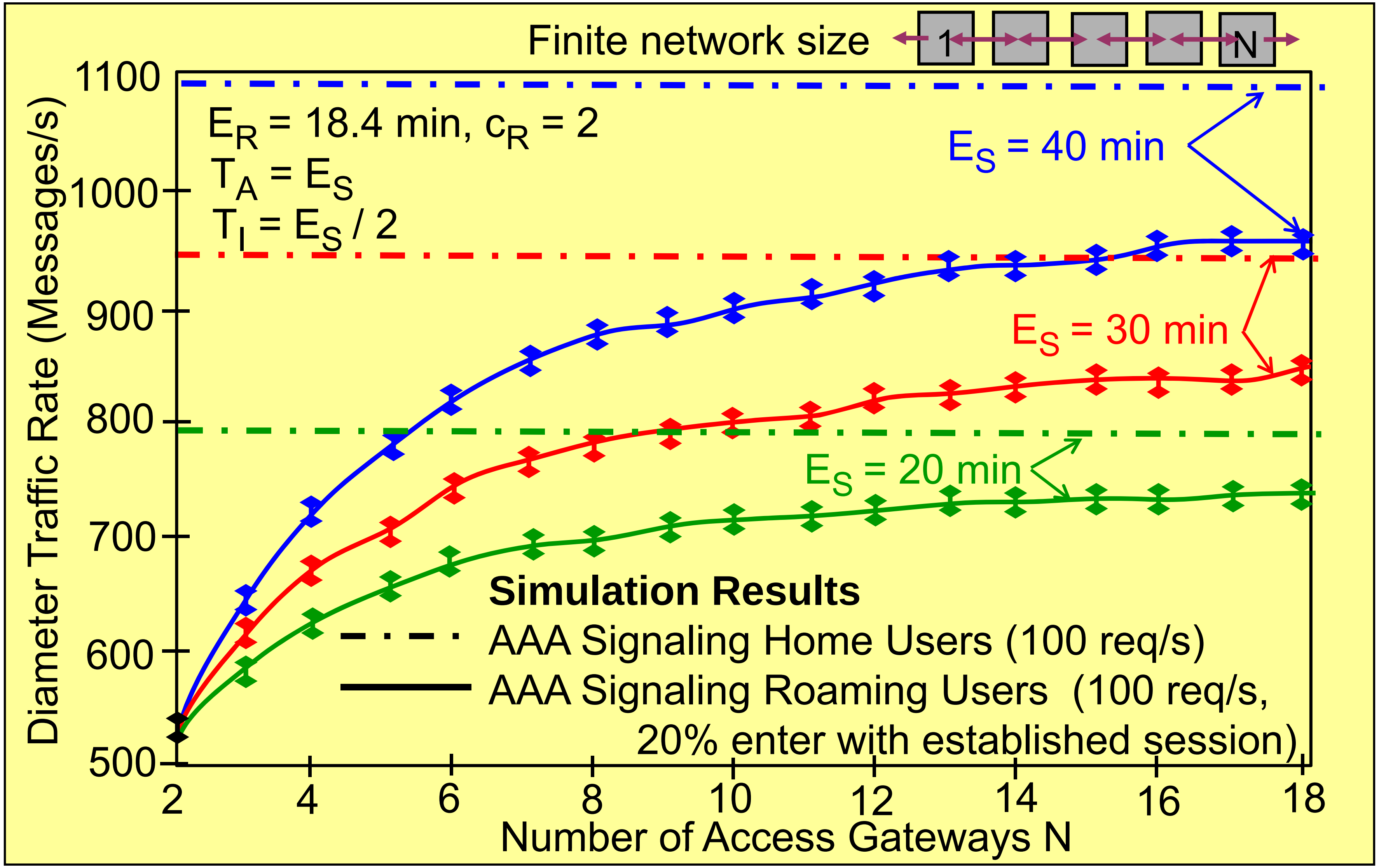
Residence Time Effect on the Signaling Rate



Interim-Interval Effect on the Signaling Rate



Network Size Effect on the Signaling Rate

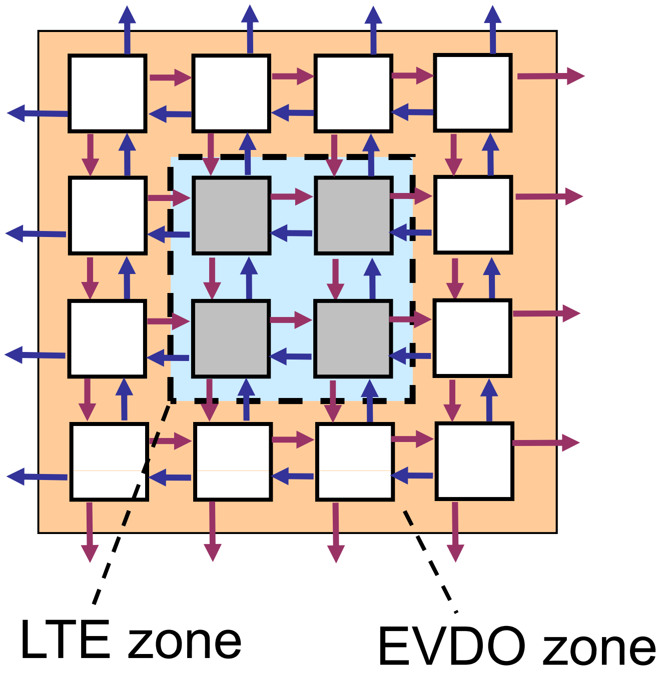


Inhomogeneous Network Architecture and Mobility Pattern

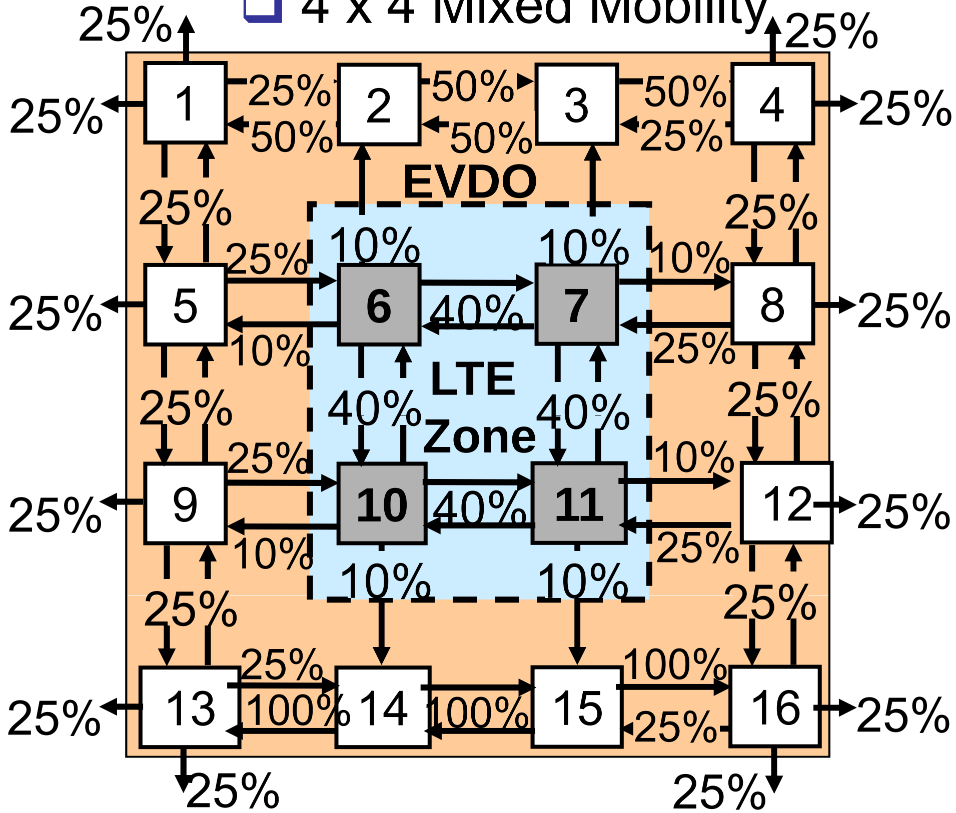
- Network is composed of 16 different areas
  - EVDO zone: 12 areas using 3G technology; mean R_{EVDO}
  - LTE zone: 4 areas using 4G technology; mean R_{LTE}

- Random Mobility 4x4

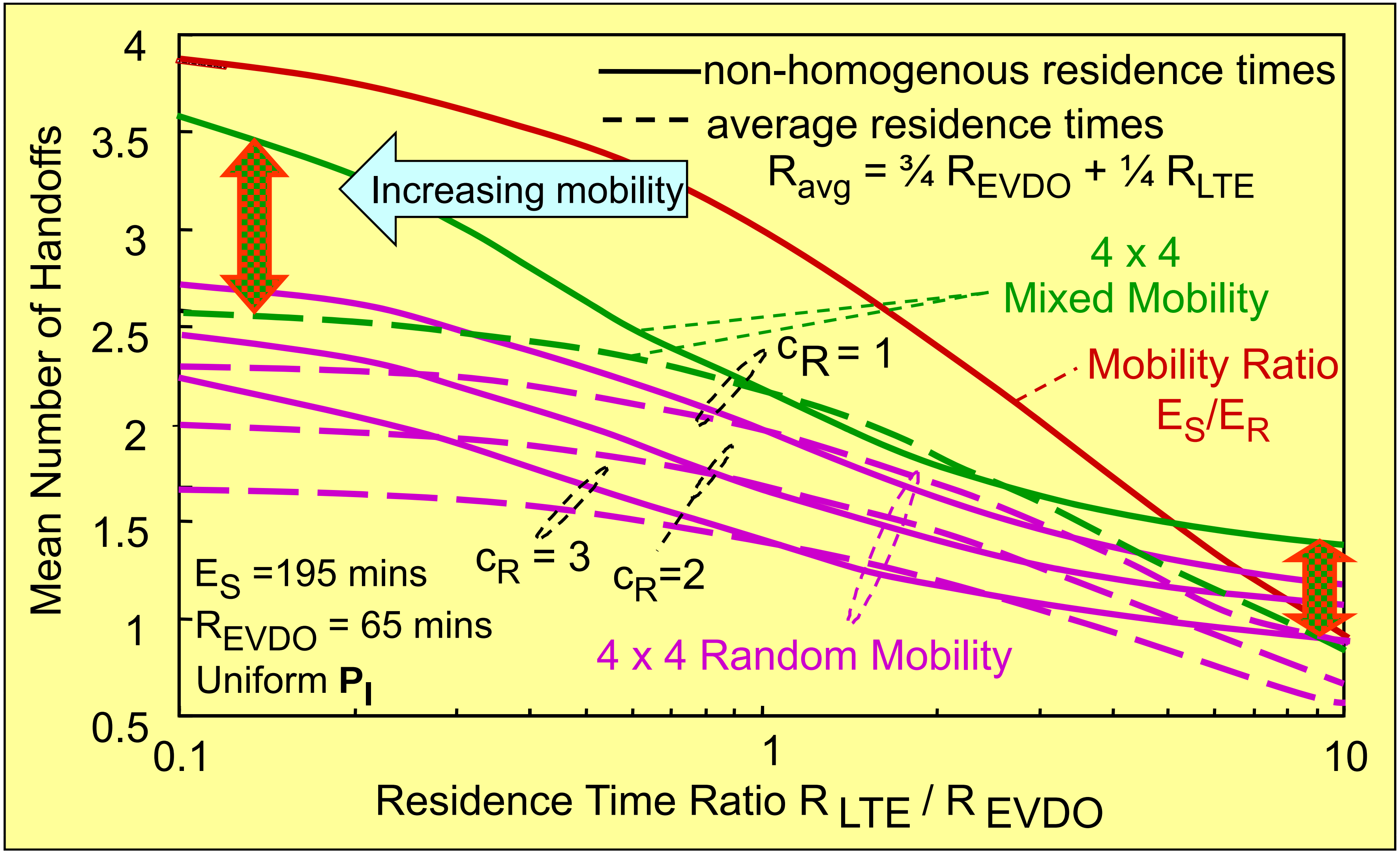
$$p_{jxy} = 0.25 \quad \forall (x,y)$$



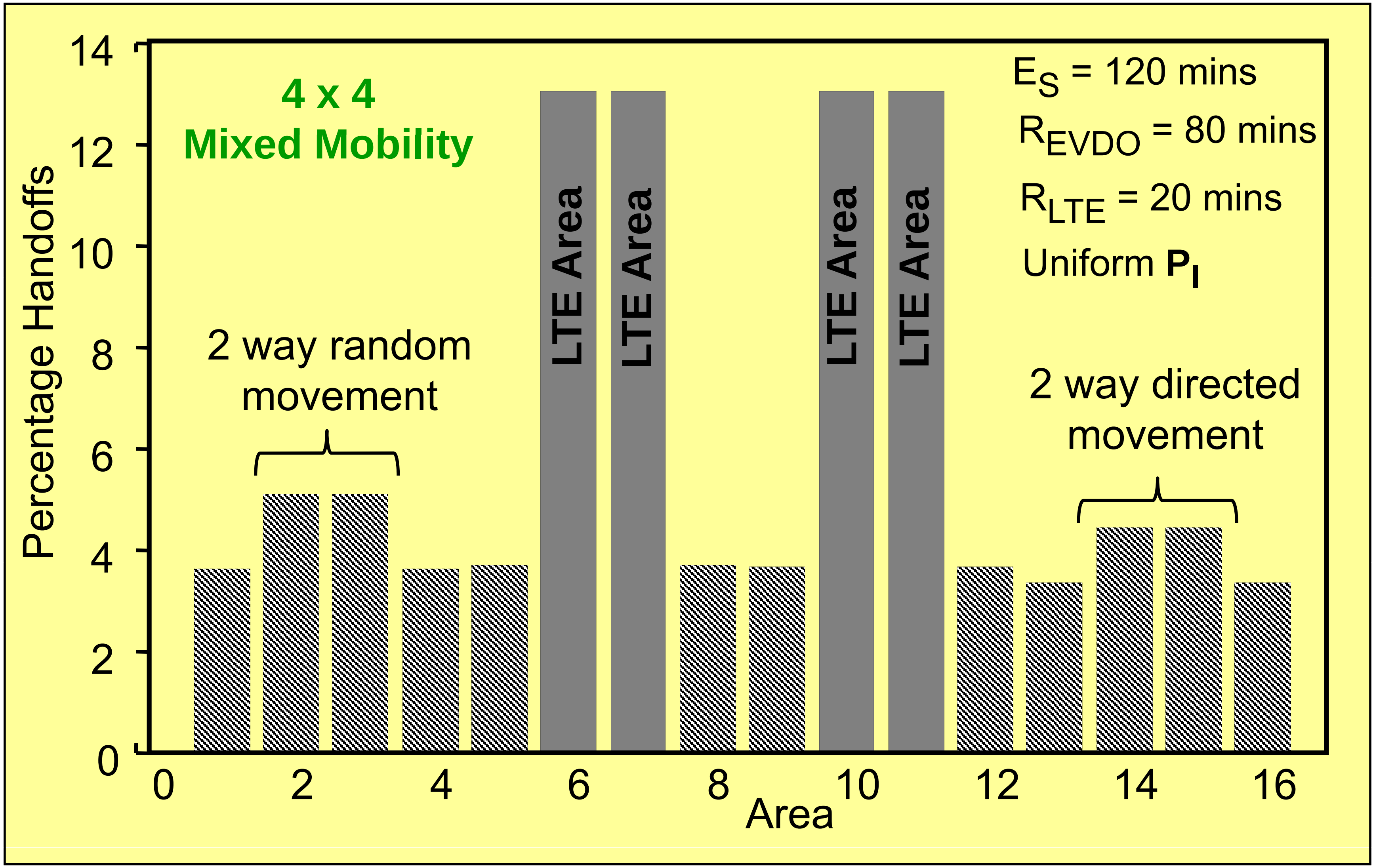
- 4 x 4 Mixed Mobility



Mean Number of Handoff versus Residence Time Ratio



Handoff Rate Distribution between LTE / EVDO Areas



Conclusions

A mathematical framework has been derived for the

- Analysis of the signaling rate due to the Diameter protocol
  - taking into account relevant protocol parameters
- Analysis of the handoff statistics
  - taking into account
    - non identically distributed residence times
    - general distributed session holding times
    - the spatial arrangement of finite netwok sizes
    - a generic Markovian mobility model
- This work can be extended to include
  - blocking of calls due to limited resources
  - detailed performance analysis of signaling protocols (e.g. Diameter with Proxy Mobile IP or Extensible Authentication Protocol (EAP))

Conclusions (2)

- Beyond IP
  - AAA security mechanism for Inter-Domain provisioning and Routing in Carrier-Grade Ethernet (100 GET)

- Challenging problems for the AAA signaling traffic
  - generalized modeling, measurement and analysis of the channel holding time
  - generalized modeling of the remaining session holding time

Thank you

for your attention