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An Optimal Resource Assignment for C/D-plane Virtualized Mobile Core Networks

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Background

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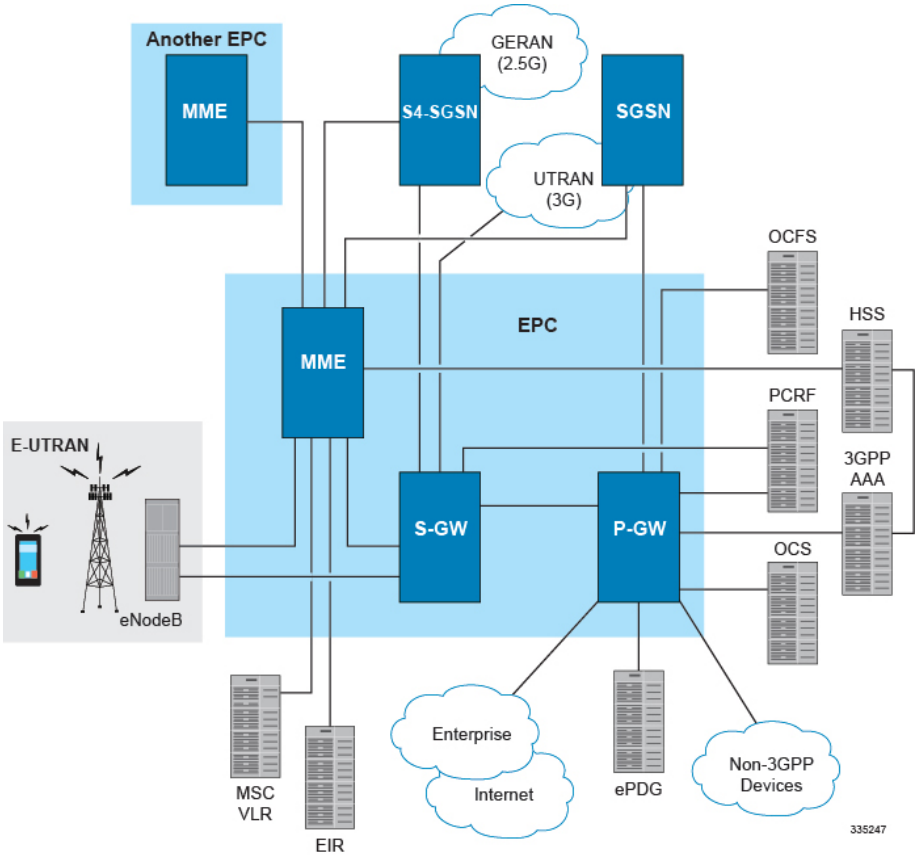
- Drastic increase in mobile traffic
  - Migration from 4G to 5G
- Rise of M2M (Machine-to-Machine) communications
  - Autonomous car, AR(Augmented Reality) etc.

Characteristics of M2M Communications

- Allowable delay: Strict
  - Faster response is required
- Data packet size: Small
- Signaling: Frequent
  - Congestion on not only D-plane but also C-plane

EPC (Evolved Packet Core)

Equipment of the 4G core network



(MME Administration Guide, StarOS Release 21: Mobility Management Entity Overview
http://www.cisco.com/c/en/us/td/docs/wireless/asr_5000/21/MME/b_21_MME_Admin/b_21_MME_Admin_chapter_01.html)

Main Entities of EPC

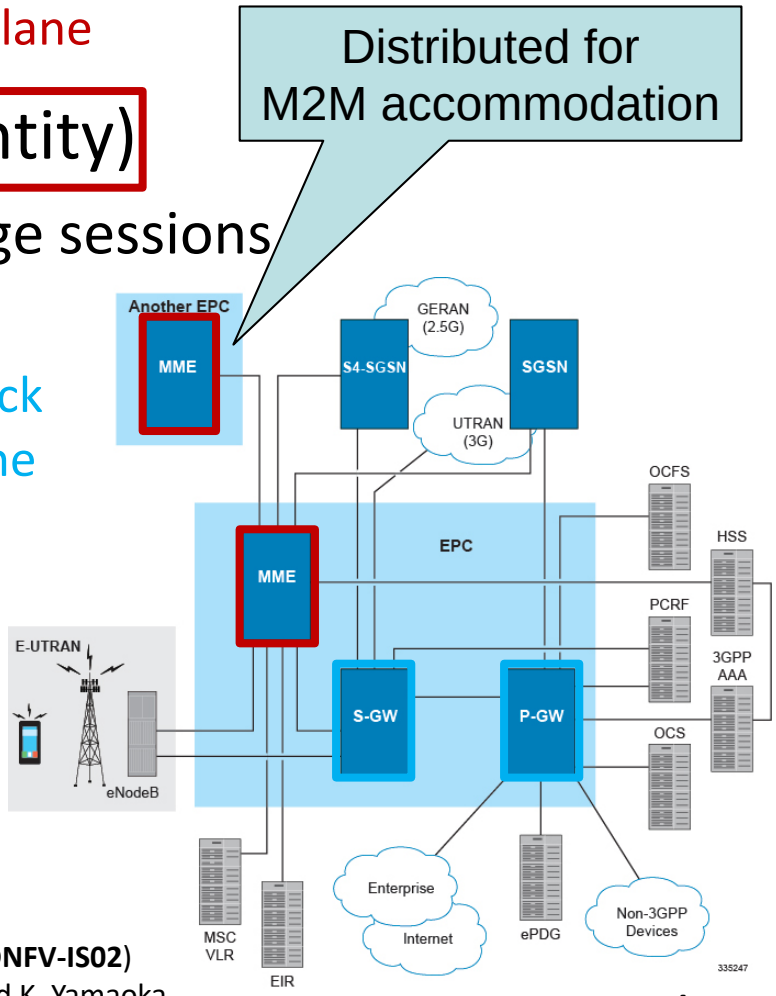
- eNodeB (Evolved NodeB)
  - Base station

Bottleneck of C-plane

- MME (Mobility Management Entity)
  - Process signaling packets, manage sessions
- S-GW (Serving Gateway)
  - Connect to 3G networks

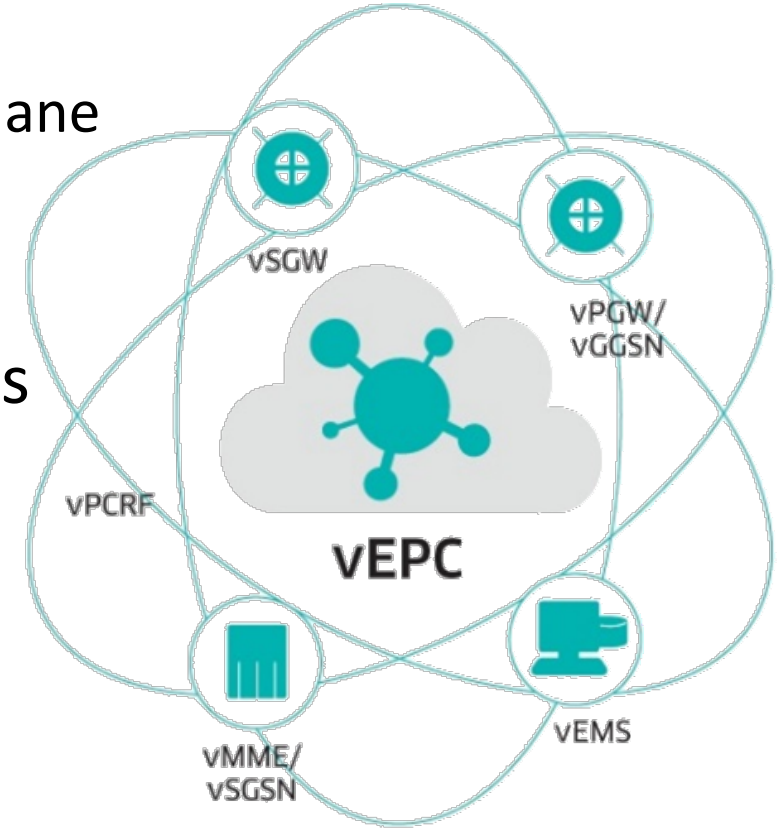
Bottleneck of D-plane

- P-GW (PDN Gateway)
  - Connect to external networks



vEPC (Virtualized EPC)[1]

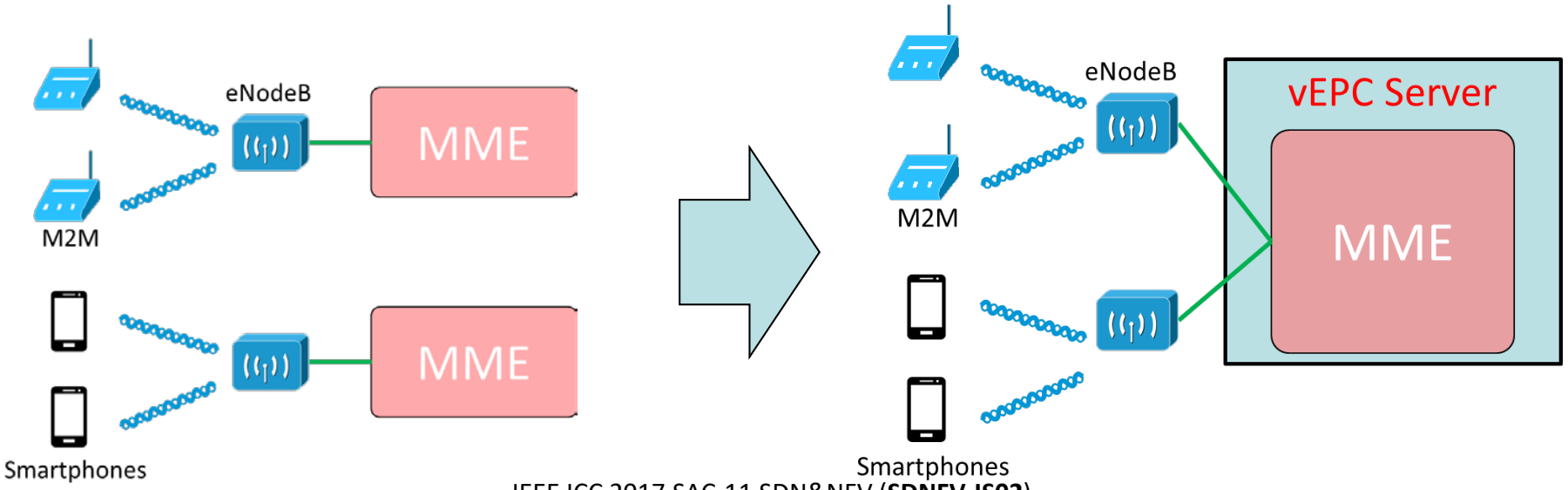
- Deploy functions of EPC entities as VNFs
  - Reduce CAPEX, OPEX
    - Virtualization of both C/D-plane is more cost-effective
  - Flexible deployment according to traffic demands



[1]H. Hawilo, A. Shami, M. Mirahmadi, and R. Asal, "NFV: State of the Art, Challenges, and Implementation in Next Generation Mobile Networks (vEPC)," IEEE Network, vol.28, no.6, pp.18–26, Nov. 2014.

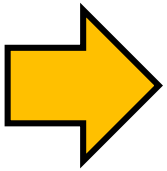
A Problem of vEPC Networks

- Allowable Delay of M2M Communications
  - The same MME resource is shared with smartphones
    - Conventional: Distributed for M2M devices
  - Congestion slows signaling processing power
    → M2M allowable delay cannot be satisfied !



Strategy

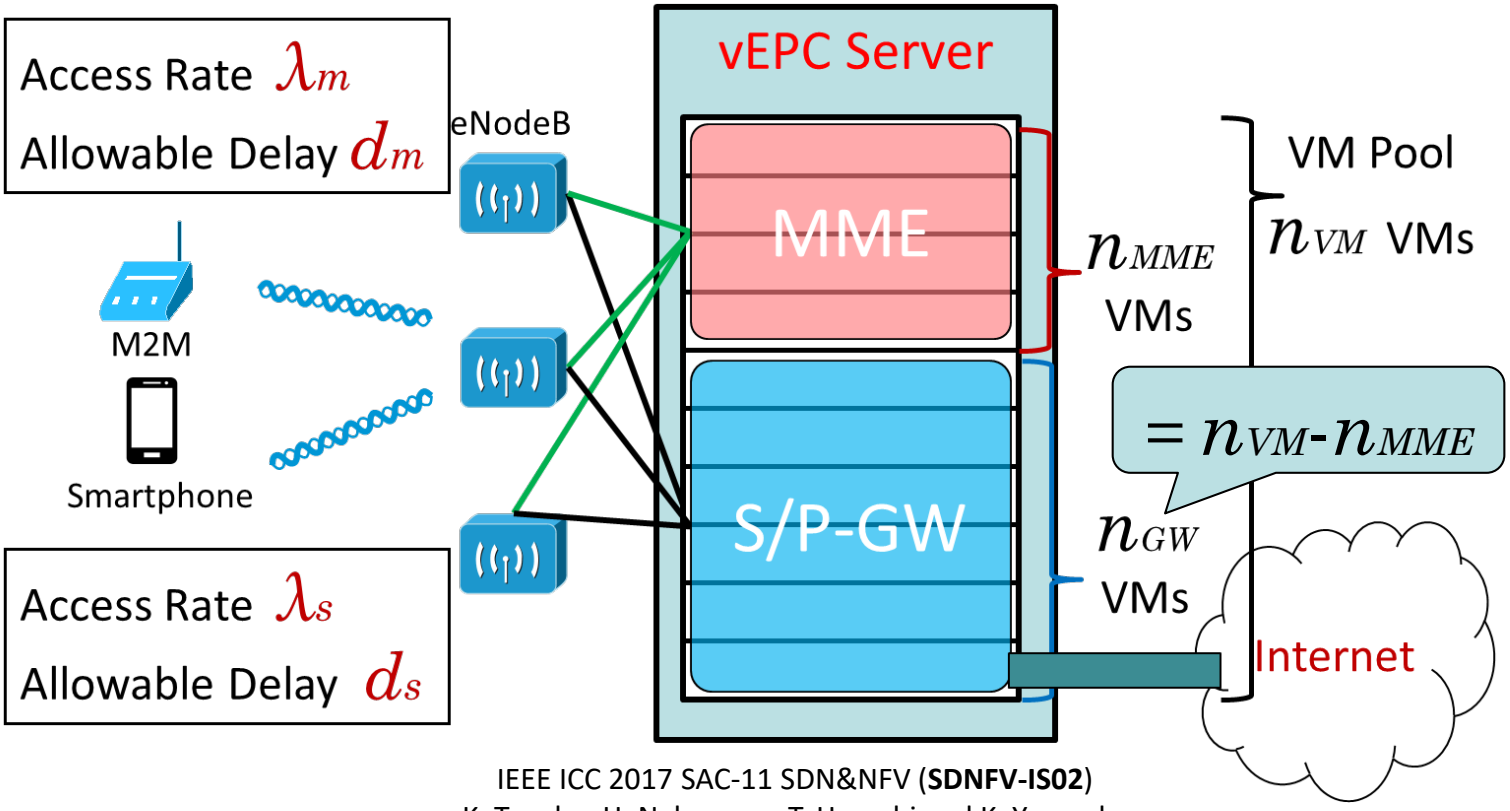
- When both C/D-plane are virtualized in a single vEPC Server…
  - Fixed amount of hardware resource
  - In consideration of different traffic requirements:
    - Signaling Frequency: M2M High Smartphone Low
    - Data Packet Size: M2M Small Smartphone Large
    - Allowable Delay: M2M Strict Smartphone Tolerant



vEPC-ORA Method

Network Model

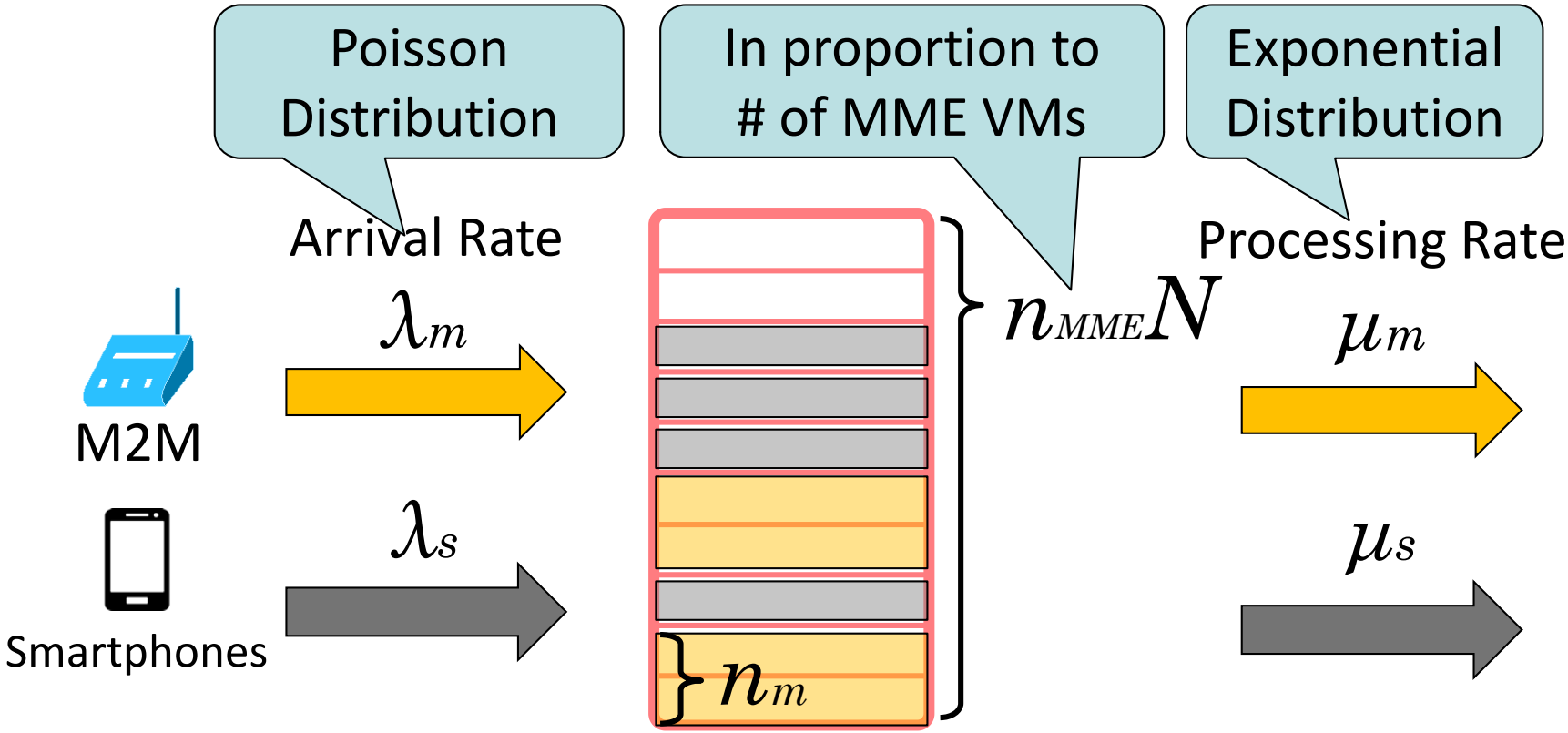
- Modeled a vEPC Server as a VM Pool
  - Migrate MME and S/P-GW VNFs



Model Settings of MME

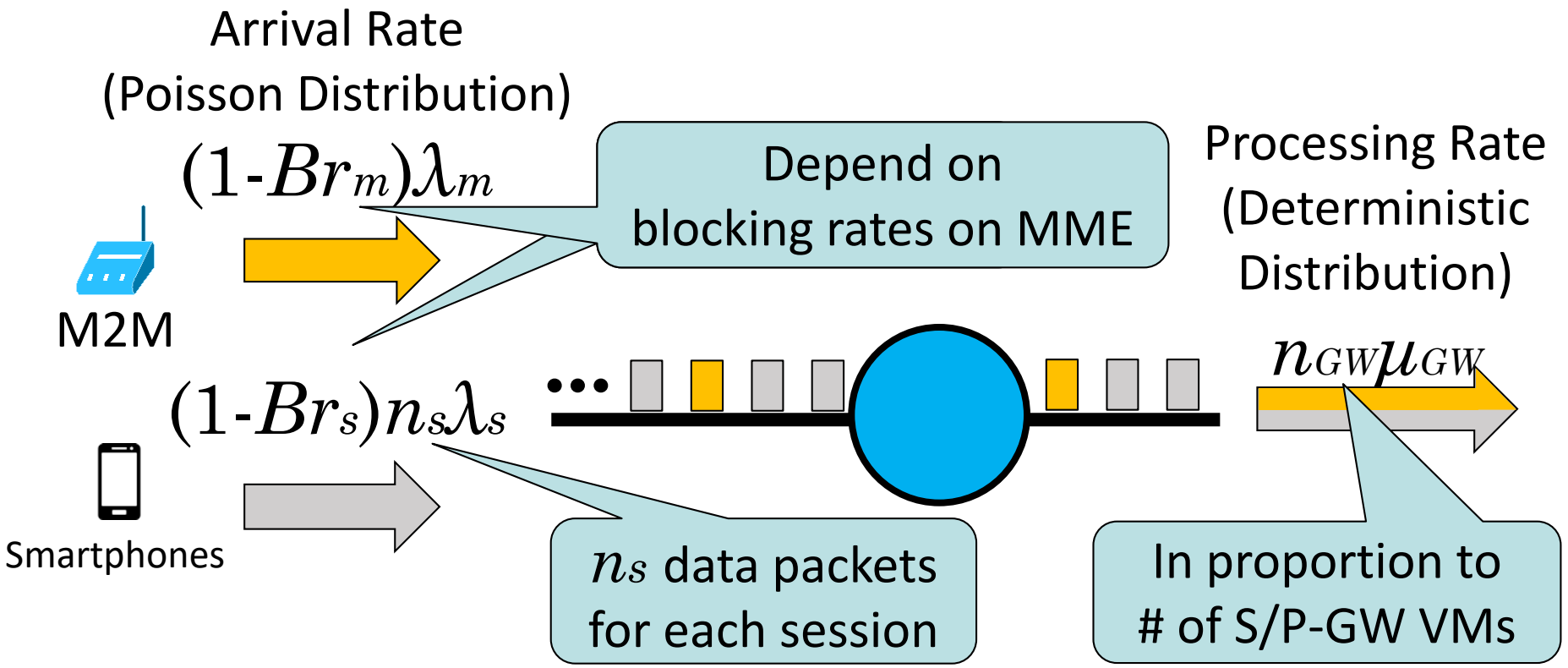
Session Pool

- $M_1,M_2/M_1,M_2/n_{MME}N/n_{MME}N$ queueing loss system

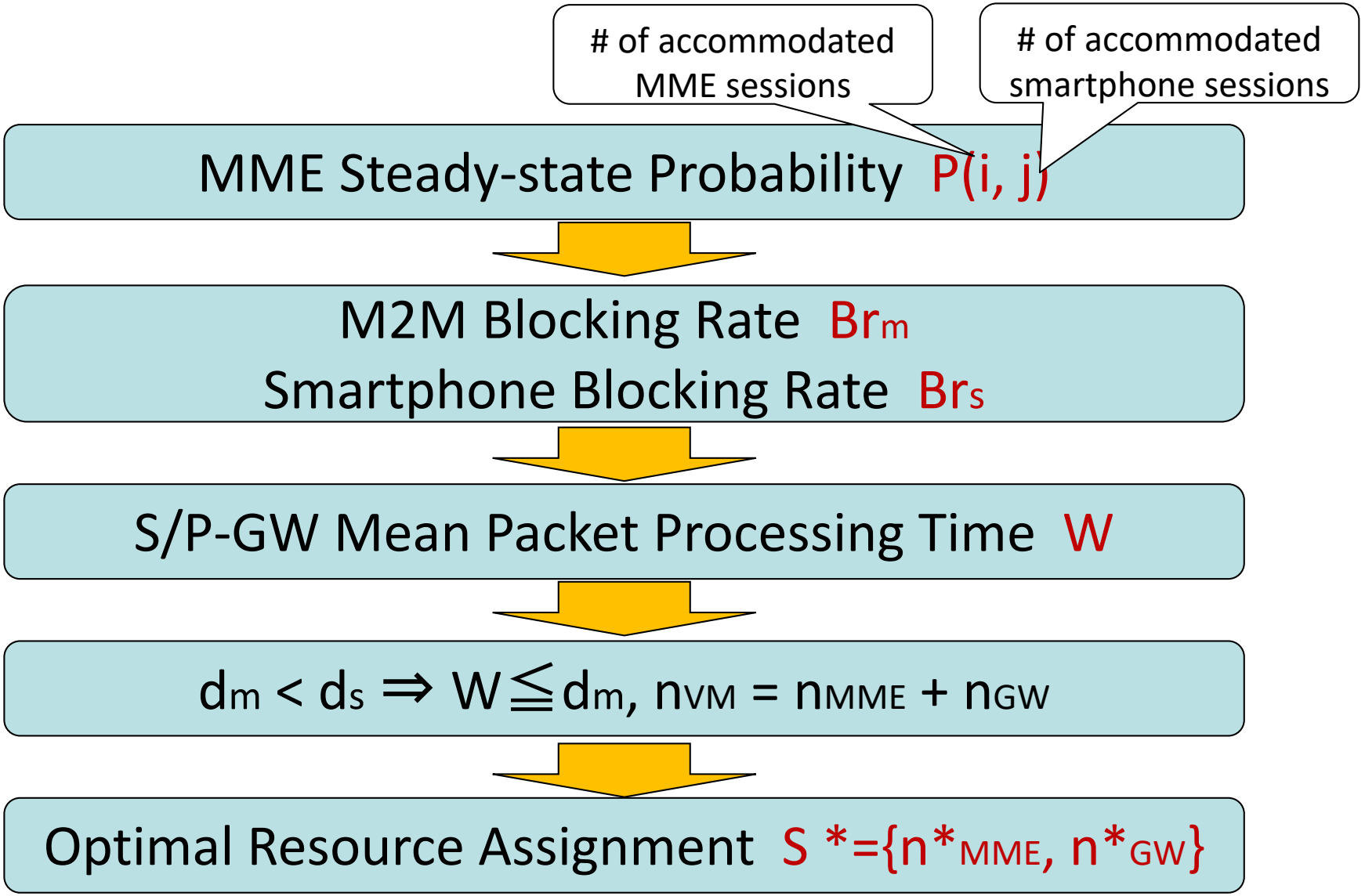


Model Settings of S/P-GW

- $M_1, M_2/D/1$ queueing delay system



Outline of vEPC-ORA method



vEPC-ORA Method

- Optimal Resource Assignment S*
  - Optimal resource assignment of MME and S/P-GW S*={n*$_{MME}$, n*$_{GW}$} is calculated as:

$$S^* \in \underset{n_{MME}, n_{GW}}{\arg\min} \; Br_m$$

$$s.t. \;\; n_{MME} + n_{GW} = n_{VM}, \;\; n_{GW} \geqq \frac{\Lambda + D}{2\mu_{GW}}$$

$$\left(\begin{array}{c} \Lambda = (1 - Br_m)\lambda_m + (1 - Br_s)n_s\lambda_s, \\ D = \sqrt{\Lambda^2 + \frac{2\Lambda}{d_m}} \end{array} \right)$$

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Parameter Settings

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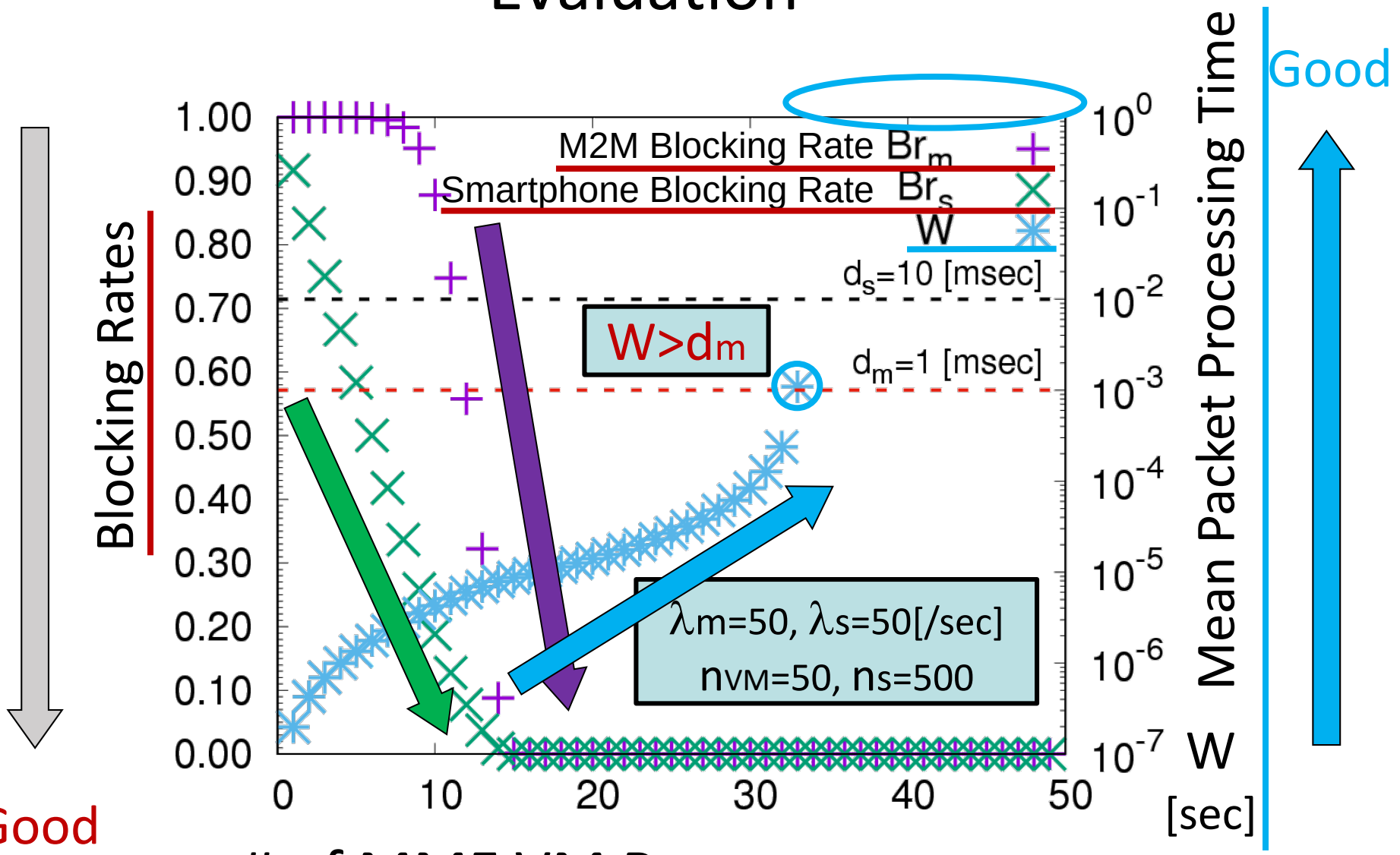
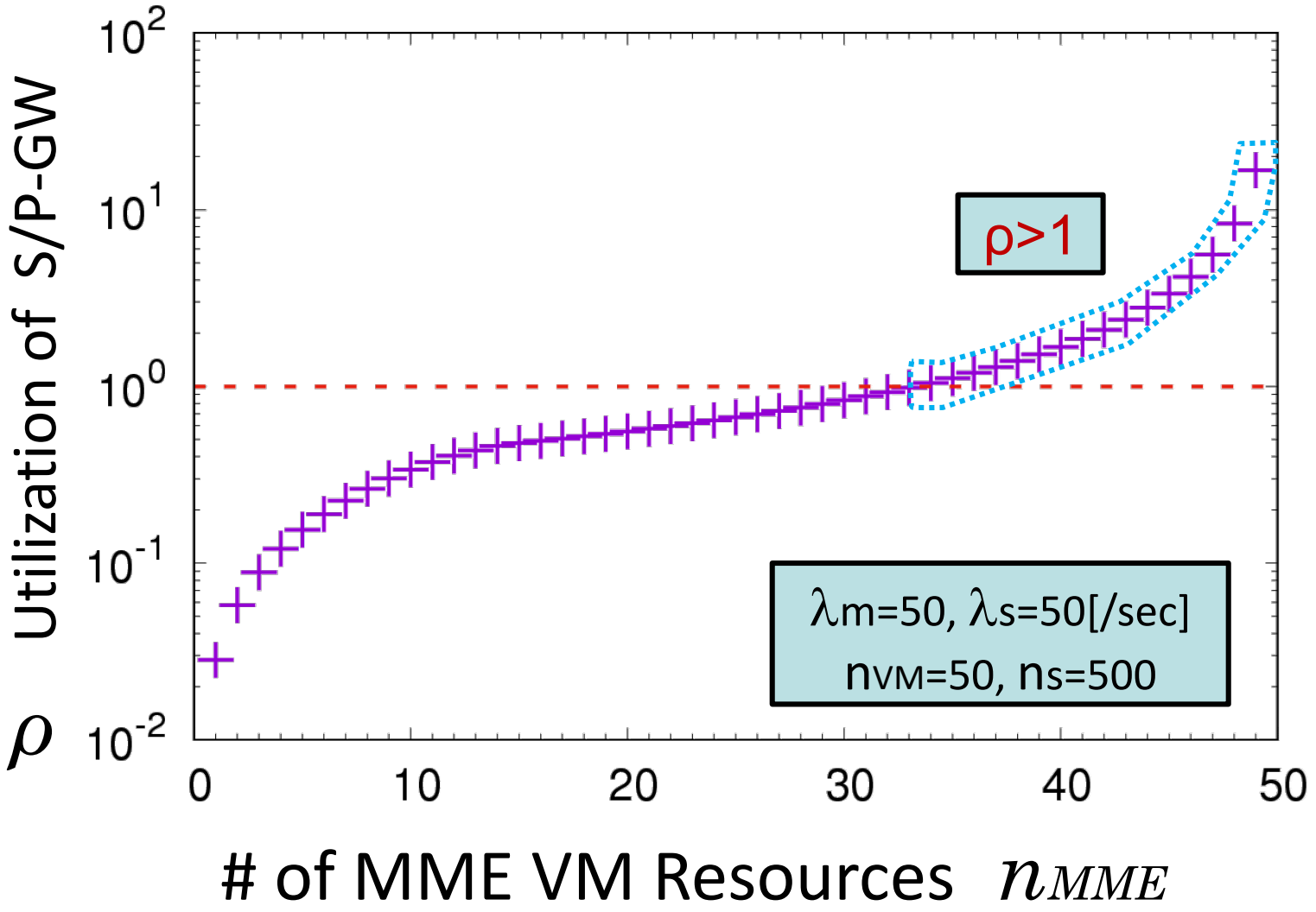
# of VM Resources n_{VM}	50
M2M Access Rate λ_m	50 [/sec]
Smartphone Access Rate λ_s	50 [/sec]
M2M Session Holding Time μ_m	1 [sec]
Smartphone Session Holding Time μ_s	60 [sec]
M2M Allowable Delay d_m	1 [msec]
Smartphone Allowable Delay d_s	10 [msec]
# of Session Resources per M2M Sessions n_m	10 ($=\lfloor d_s/d_m \rfloor$)
# of User Data Packets per Smartphone Session n_s	500
# of Session Resource per MME VM N	250
Processing Rate per S/P-GW VM μ_{GW}	1500 [pps]

Evaluation


Blocking Rates
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
10
20
30
40
50
M2M Blocking Rate Br_m
Smartphone Blocking Rate Br_s
W
d_s=10 [msec]
d_m=1 [msec]
W>dm
λm=50, λs=50[/sec]
nVM=50, ns=500
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
Mean Packet Processing Time
W
[sec]
Good
Good
# of MME VM Resources n_{MME}

Utilization of S/P-GW



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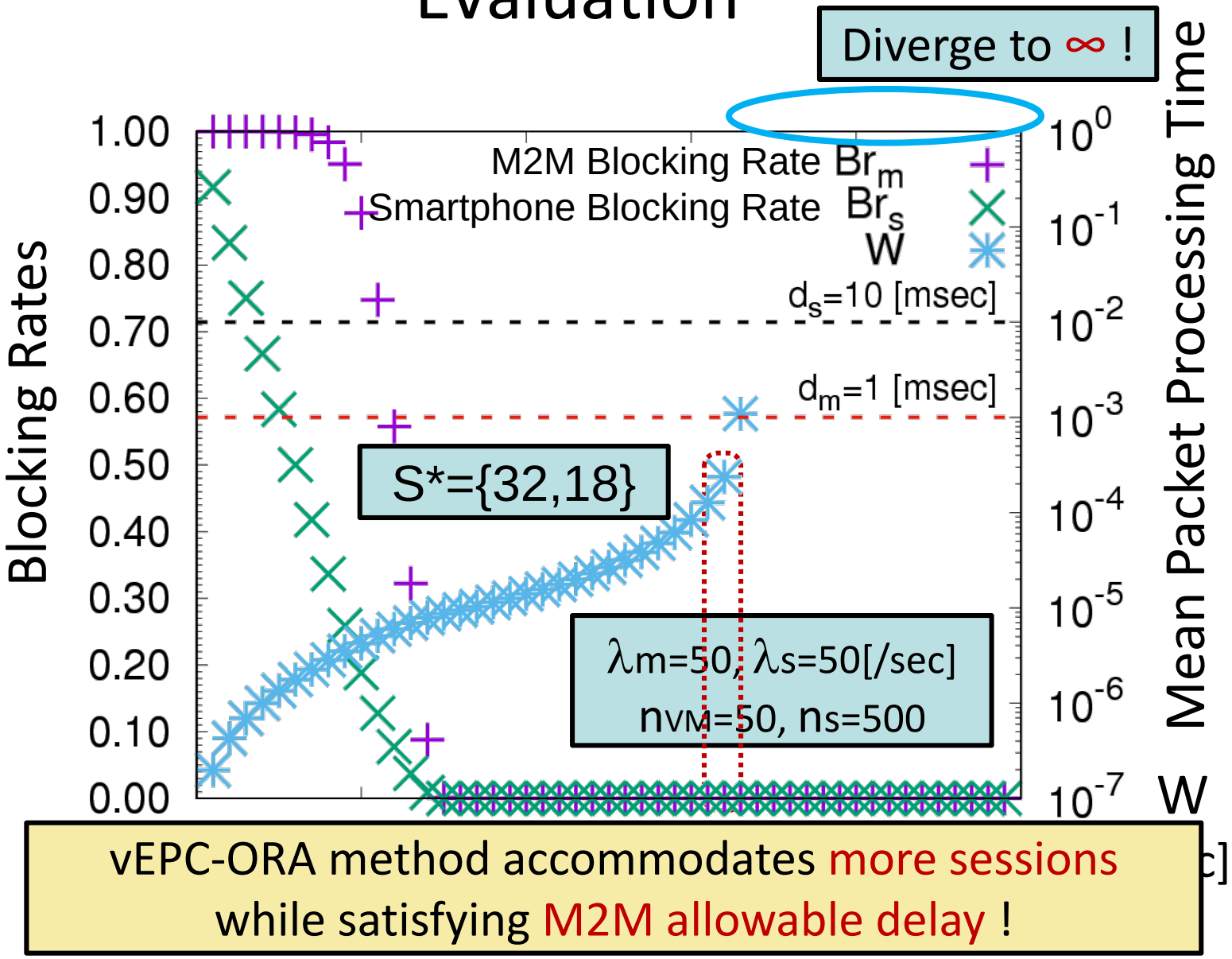
Evaluation



vEPC-ORA method accommodates more sessions while satisfying M2M allowable delay !

Summary & Future Works

Summary

- We proposed the vEPC-ORA method for optimize resource assignments of MME and S/P-GW
- Modeled a single vEPC server as a VM pool and modeled MME and S/P-GW as queueing systems
- Evaluated the accommodation effect of the vEPC-ORA method by a comparison with brute force calculation

Future Work

- Study on resource granularity
- Divide MME session pool for each communication type