System and application performance of function placement strategies for virtualized mobile fronthaul / backhaul networks

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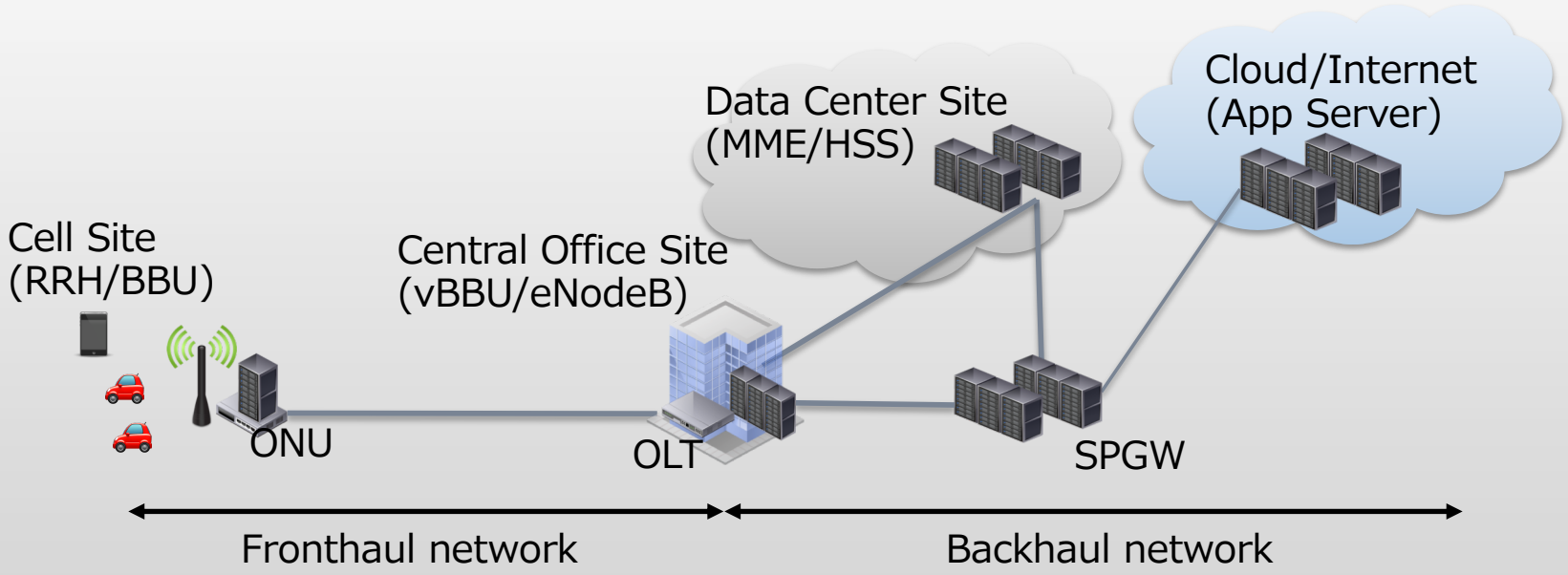
Mobile fronthaul / backhaul integrated networks

- Network and computing resources are shared by fronthaul network and backhaul network functions based on SDN/NFV technologies
  - Better resource utilization, power consumption and application performance can be expected



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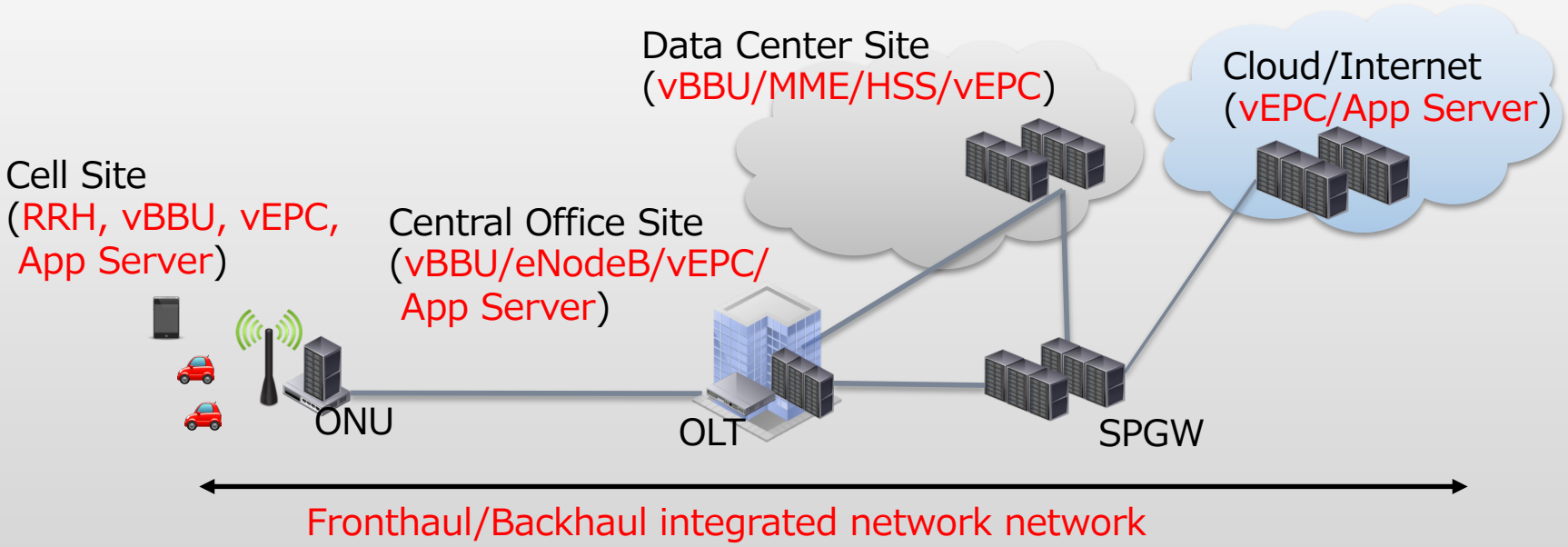


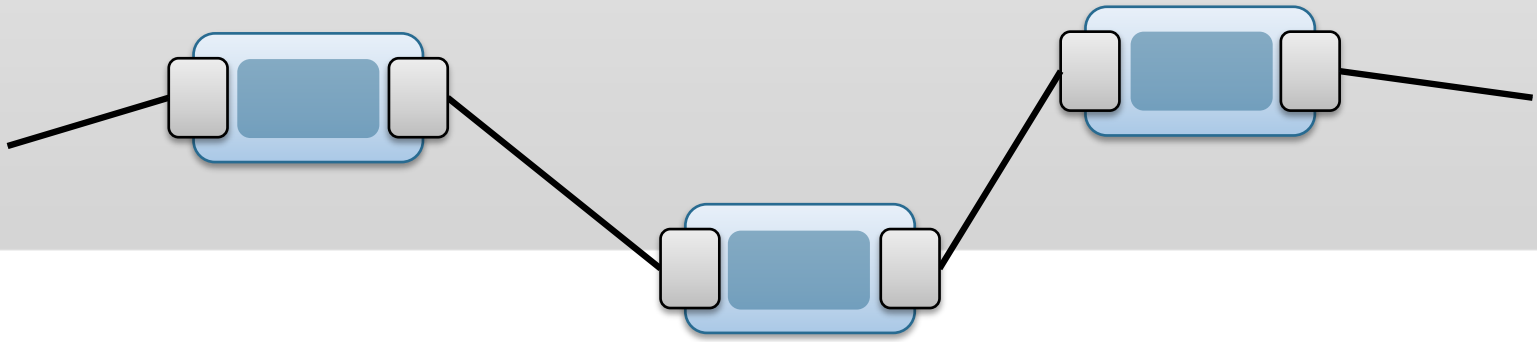
Research motivation and objectives

- Effect of integrated network has been discussed, but almost NO quantitative performance evaluation is found in existing research

- Research objectives:
  - Reveal the advantage of mobile fronthaul / backhaul integrated network by quantitative evaluations
- Methods:
  - Construct mathematical model for performance evaluation of mobile fronthaul / backhaul integrated networks
  - Conduct numerical evaluation of the analysis model
    - Discuss the effect of function placement on power consumption of the network and application performance (latency and packet loss rate)

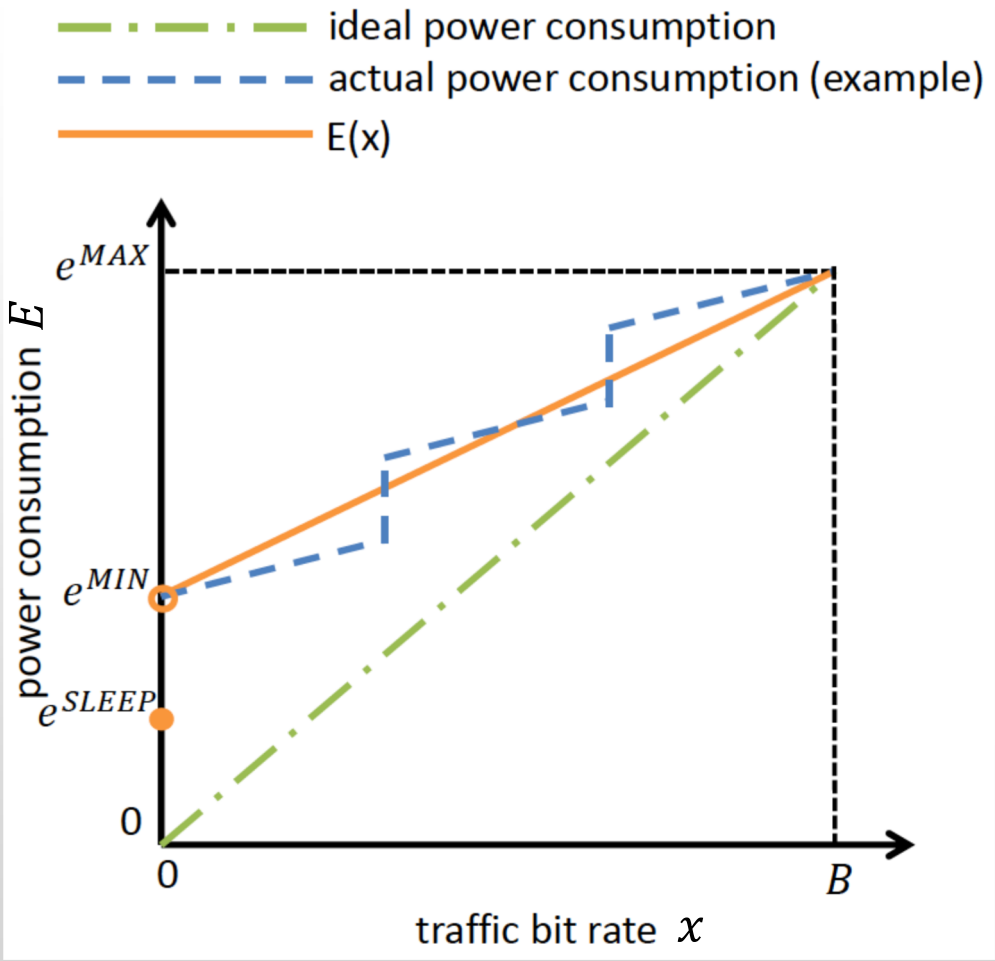
Network model

- Node
  - Has interface(s) to connect other nodes, constructing network
  - Has processing unit to execute network functions
- Processing unit
  - vBBU, vEPC, eNodeB, MME, Application servers, …
  - A virtual machine is required for executing network functions
- Network Interface
  - Makes point-to-point or point-to-multipoint link to other node(s)
- Link
  - Has bandwidth and propagation delay between interfaces



Power consumption model

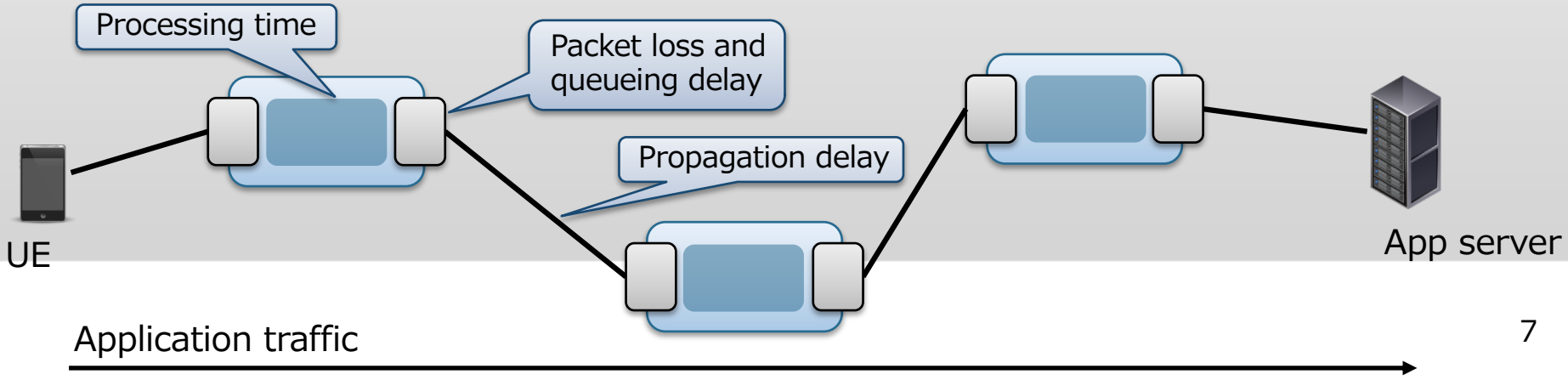
- For computing power consumption of the whole system
  - Nodes
  - Network interfaces
  - Processing units
- Linear model [10] with sleep mode
  - $E = \begin{cases} \frac{e^{MAX} - e^{MIN}}{B} x + e^{MIN} & x > 0 \\ e^{SLEEP} & x = 0 \end{cases}$



[10] P. Mahadevan, P. Sharma, S. Banerjee, and P. Ranganathan, *A Power Benchmarking Framework for Network Devices*, pp. 795–808. Springer Berlin Heidelberg, May 2009.

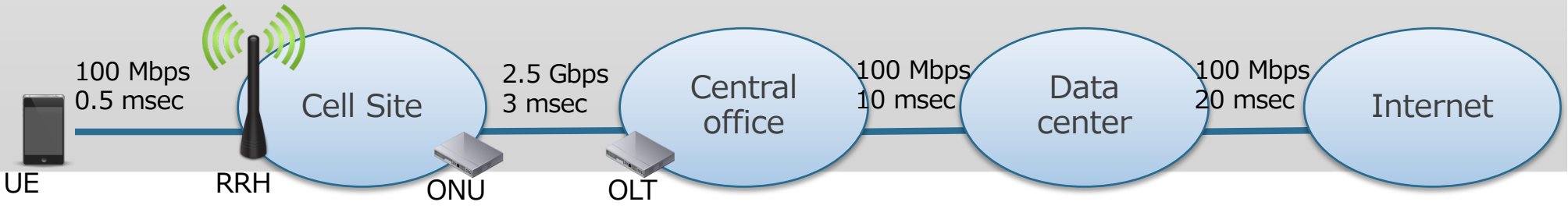
Application traffic performance

- End-to-end Packet loss rate
  - Calculated from packet loss rates at network interface on the path between a UE and an App server
  - M/M/1/K queueing model is applied
- End-to-end latency
  - Sum of propagation delays, node processing time, and queueing delay at network interfaces
  - Propagation delays: Calculated from link distances on the path
  - Node Processing time: Calculated by M/G/1/PS queueing model
  - Queueing delay: Calculated by M/M/1/K queueing model



Numerical evaluation environment

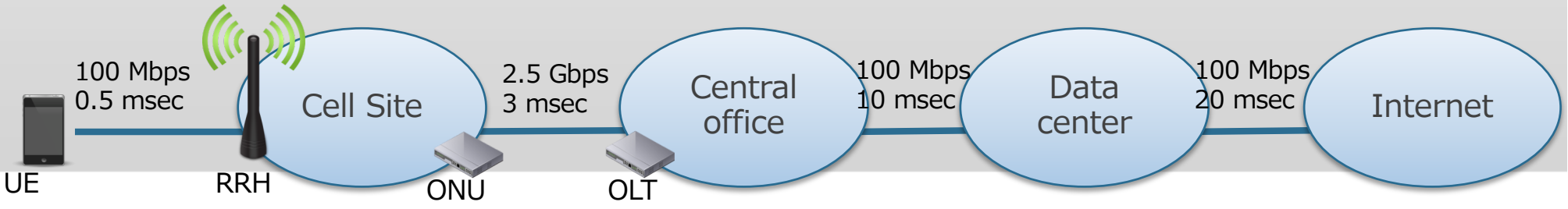
- Straight-line topology with four sites
  - Cell site, Central office, Data center, and Internet
- vBBU, vEPC, Application server are placed to one of the sites
- Upward traffic from a UE to an Application server
  - Packets are processed at vBBU, vEPC, and Application server
- Performance evaluation metric
  - Power consumption of whole system
  - Application traffic performance
    - End-to-end packet loss rate
    - End-to-end latency



Evaluation scenario

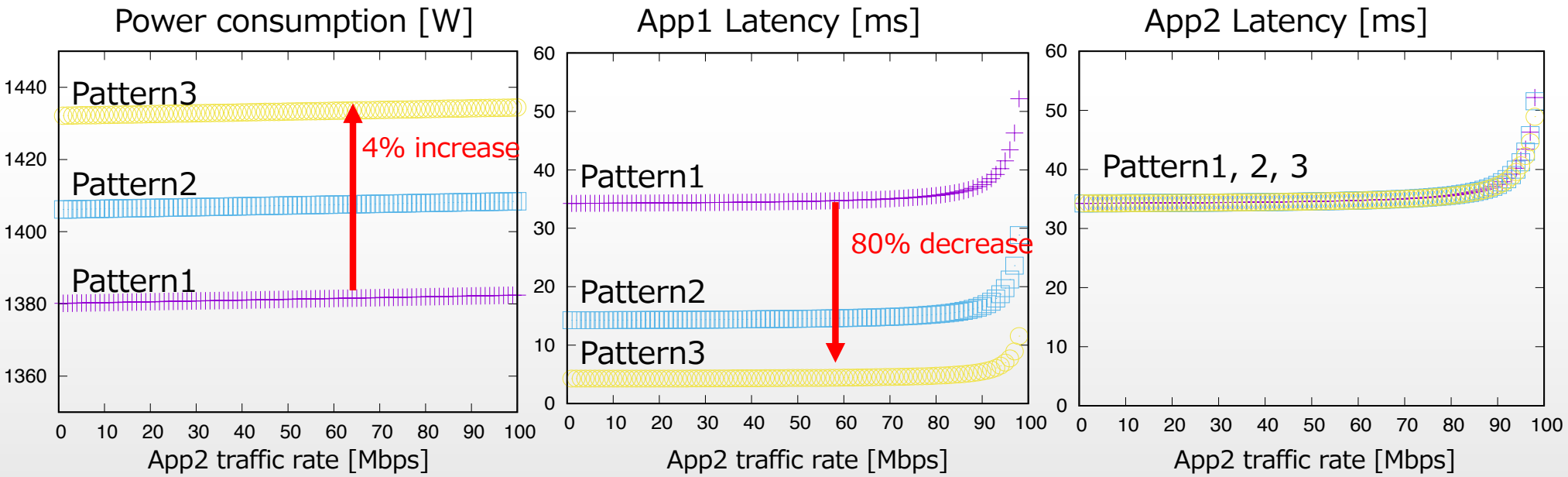
- Two applications on a UE generate traffic to application servers
  - App1: 1Mbps
  - App1: 1 – 100Mbps
- Assess the effect of placements of network functions

Pattern	Cell site	Central office	Data center	Internet
1		vBBU	vEPC1 vEPC2	App1 Server App2 Server
2		vBBU	vEPC1, vEPC2, App1 Server	App2 Server
3		vBBU, vEPC1, App1 Server	vEPC2	App2 Server
4	vBBU, vEPC1, App1 Server		vEPC2	App2 Server



Application traffic

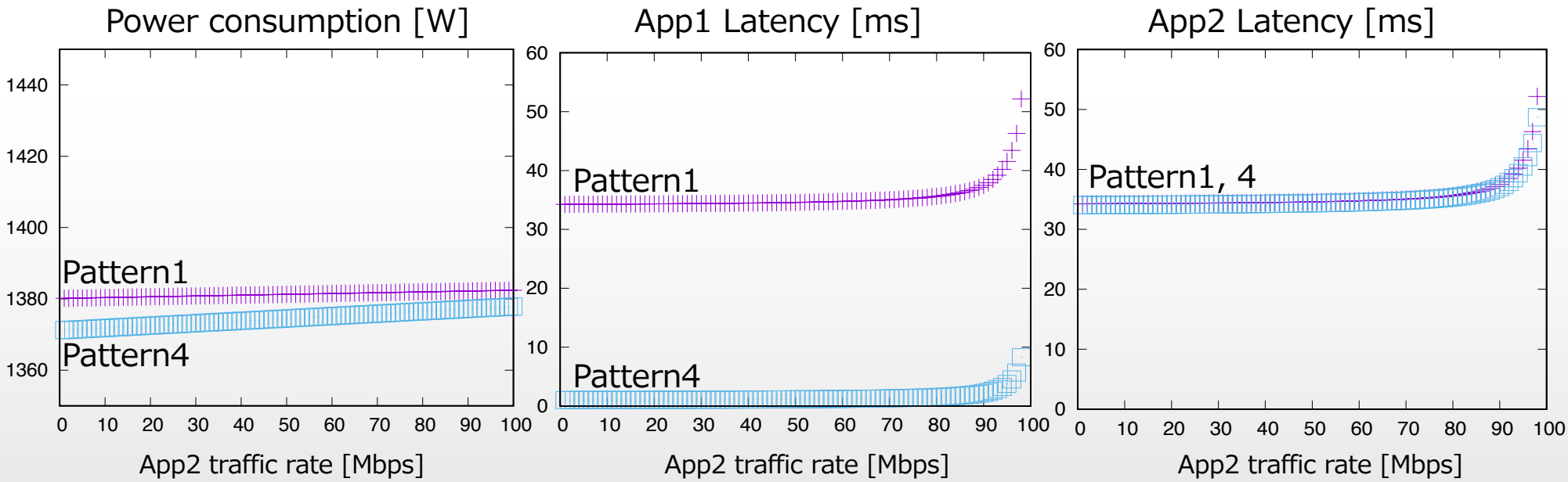
Evaluation results (1): Placement of App1 server



- Power consumption slightly increases by moving App1 functions closer to UE
  - The number of VMs required for network functions increased
- End-to-end latency of App1 greatly reduced, while the performance of App2 remains almost unchanged

Pattern	Cell site	Central office	Data center	Internet
1		vBBU	vEPC1, vEPC2	App1 Server, App2 Server
2		vBBU	vEPC1, vEPC2, App1 Server	App2 Server
3		vBBU, vEPC1, App1 Server	vEPC2	App2 Server

Evaluation results (2): vBBU placement



- Power consumption decreases by placing vBBU at cell site
  - Network traffic between cell site and central office is significantly reduced
- End-to-end latency of App1 greatly reduced by placing all functions at cell site, without sacrificing App2 performance
  - Requires large processing capacity at cell site

Pattern	Cell site	Central office	Data center	Internet
1		vBBU	vEPC1 vEPC2	App1 Server App2 Server
4	vBBU, vEPC1, App1 Server		vEPC2	App2 Server

Conclusions and future work

- Performance analysis model for mobile fronthaul / backhaul integrated networks
- Numerical examples for assessing placement strategies of network functions
  - Power consumption and application performance are significantly dependent on network function placement
- Future work
  - Evaluations for large-scale networks
  - Formulation of function placement problem based on the analysis model