Joint bearer aggregation and control-data plane separation in LTE EPC for increasing M2M communication capacity

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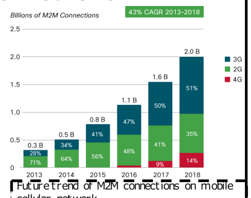
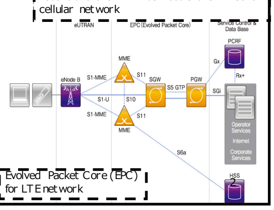
M2M (IoT) traffic on mobile cellular networks

- M2M (Machine-to-Machine) communication
  - Smaller transmitting/receiving data per communication
  - Larger number of devices connected
  - Smaller ARPU (Average Revenue Per User) than traditional mobile phones
- Cannot recover the cost for accommodating M2M UEs (terminals) connected to mobile cellular networks with conventional Evolved Packet Core (EPC)
  - Congestion of control plane in mobile core network



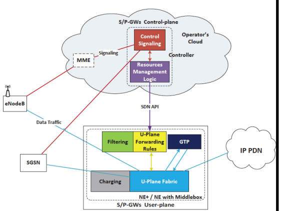
Future trend of M2M connections on mobile cellular network



Evolved Packet Core (EPC) for LTE network

Virtualization and plane separation of EPC functions

- Virtualization
  - High server resource utilization
  - Flexible server scaling according to traffic demand changes
- Plane separation
  - Separates data plane and control plane of EPC functions
  - Hosts control planes on cloud-based computing environment
    - Pros: low-latency signaling inside cloud network
    - Cons: Delay between data and control planes



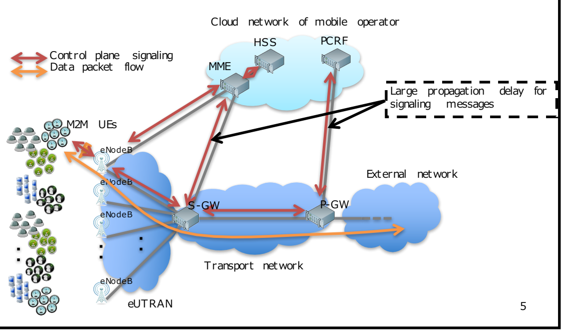
[6] A. Basta, W. Kellerer, M. Hoffmann, K. Hoffmann, and E.-D. Schmidt, "A virtual SDN-enabled LTE EPC architecture: A case study for S-/P-gateways functions," in *Proceedings of SDN4FNS 2013*, pp. 8–14b, Nov. 2013.

Research objectives

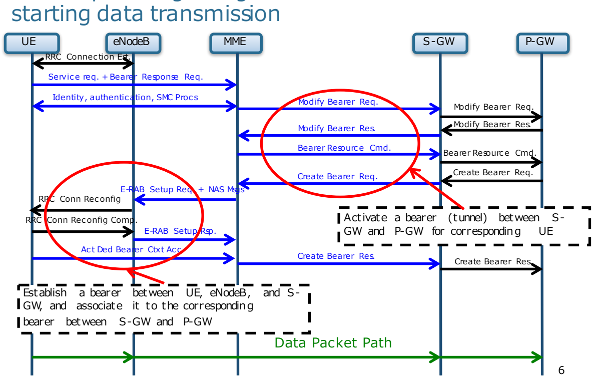
- Design and performance evaluation of virtualized, plane-separated EPC architecture for accommodating M2M traffic
  - Network architecture and changes in control plane signaling and data plane path
  - Performance evaluation
    - Calculating latency for bearer establishment and data transmission of M2M terminals
    - Effect of processing power optimization of EPC functions in cloud environment
  - Applying bearer aggregation at S-GW for further performance improvement
- Confirm the capacity improvement by the proposed architecture in terms of the number of accommodated M2M terminals

Network model for conventional EPC

- MME, HSS, PCRF nodes are located at cloud network

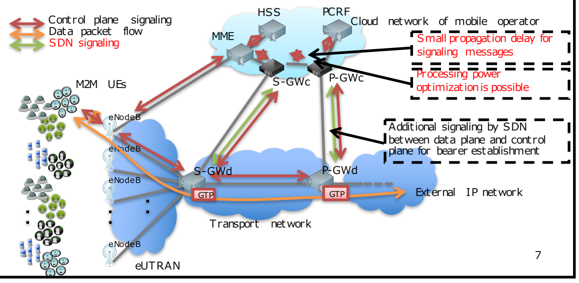


Control plane signaling for conventional EPC when starting data transmission

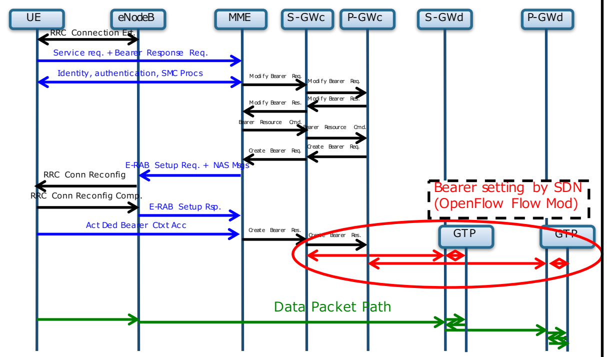


Network model for virtualized and plane-separated EPC

- Plane separation for S-GW and P-GW and their control plane nodes (S-GWc and P-GWc) are located at cloud network
- Optimization of processing power for EPC functions in cloud network
- Data plane node at GWs implements GTP tunneling matching mechanism

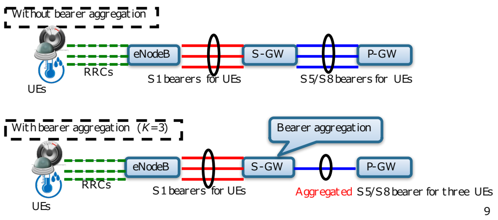


Control plane signaling for proposed EPC when starting data transmission



Bearer aggregation at S-GW

- One S1 bearer and one S5/S8 bearer for each UE in convectional EPC
  - Heavy load on GWs and MME when accommodating many M2M terminals
- Aggregate S5/S8 bearers for multiple UEs to a single bearer at S-GW
  - Pros: Number of bearers between S-GW and P-GW decreases, that reduces the processing load at GWs and MME
  - Cons: Additional processing at S-GW for aggregation

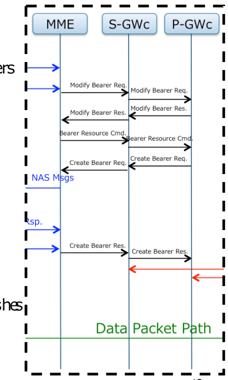


Performance analysis

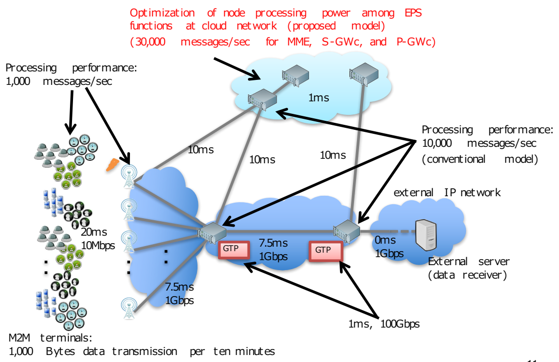
- Bearer establishment latency from when a message is generated at a UE to when bearers between UE and P-GW are established
  - Propagation delay between EPC nodes for each signaling message
    - Determined by distance between EPC nodes
  - Processing delay at EPC node of each signaling message
    - M/G/1/PS queuing model

$$E[R] = \frac{\rho^r}{1-\rho}\frac{E[S^2]}{2E[S]} + \frac{1-\rho^r}{1-\rho}E[S]$$

- Data transmission latency from when the bearers are established to when the UE finishes the transmission of data packets
  - Considering transport-layer protocol processing (TCP or UDP)

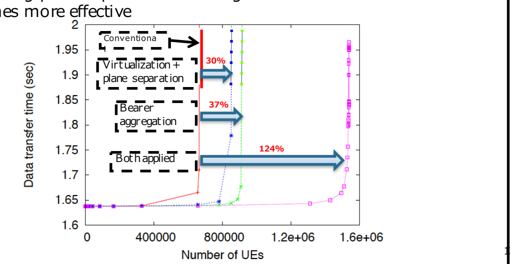


Parameter settings for numerical examples



Evaluation results: Effect of joint control

- 124% of capacity increase by joint bearer aggregation and plane separation, while 30% or 37% with only one method
  - Bearer aggregation decreases the load of MME and SGW
  - Processing power optimization among EPC functions at cloud network becomes more effective



Conclusions and future work

- New mobile core network architecture for accommodating M2M terminals effectively
  - Virtualized and plane separation of EPC functions
  - Bearer aggregation at S-GW
- Performance evaluation
  - 30% or 37% capacity increase by only plane separation or bearer aggregation
  - 124% capacity increase with combination of both methods
- Future work
  - Precise modeling of node processing delay for signaling messages
  - Performance evaluation on large-scale mobile core networks

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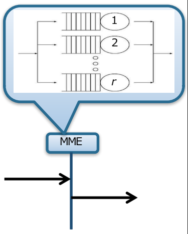
Processing model of signaling messages at EPC nodes

- Processing of signaling messages at EPC node is modeled as M/G/1/PS (r) queuing model
  - r: Number of parallel server processes
  - $S(x)$: Workload distribution
  - ρ : System utilization
  - $E[R]$: Average message processing delay

$$E[R] = \frac{\rho^r}{1-\rho}\frac{E[S^2]}{2E[S]} + \frac{1-\rho^r}{1-\rho}E[S]$$



- Calculate message processing delay from…
  - Number of accommodated UEs
  - UEs' communication frequency and data size
  - Number of signaling messages handled at EPC node

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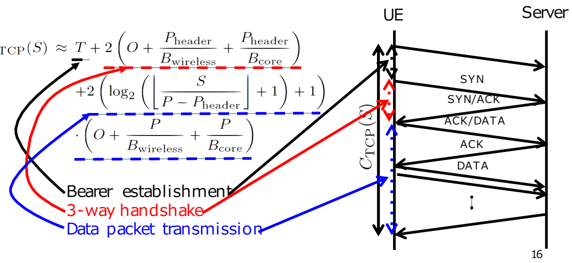
Data transmission delay

- Calculate the time for sending S [bytes] message by TCP or UDP
  - Transport-layer protocol overhead (TCP or UDP) is considered
  - O: one-way transmission delay from UE to the external server connected to P-GW

$$C_{\mathrm{TCP}}(S) \approx T + 2\left(O + \frac{P_{\mathrm{header}}}{B_{\mathrm{wireless}}} + \frac{P_{\mathrm{header}}}{B_{\mathrm{core}}}\right) + 2\left(\log_2\left(\left\lceil\frac{S}{P-P_{\mathrm{header}}}\right\rceil+1\right)+1\right)\cdot\left(O + \frac{P}{B_{\mathrm{wireless}}} + \frac{P}{B_{\mathrm{core}}}\right)$$



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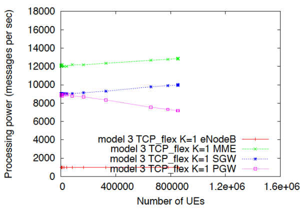
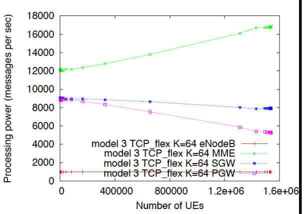
Evaluation results: Effect of joint control (2)

- By introducing bearer aggregation, more processing power is moved to MME
  - MME has the heaviest load in the current signaling procedure



Virtualized and plane-separated architecture



Virtualized and plane-separated architecture + bearer aggregation

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