A Control method for autonomous mobility management systems toward 5G mobile networks

Daichi Kominami
Osaka University, Japan

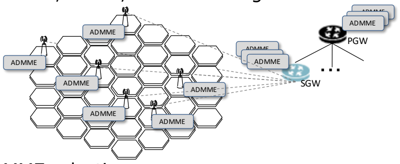
Background

- IoT and M2M communication will be critical for secure, safe, and affluent living
  - Rapid increase in mobile traffics in 5G mobile and wireless communication systems
    - Cisco predicts an over 8 times increase in mobile traffics since 2015 to 2020

Centralized managements in the user plane and the control plane in the current LTE/EPC network will suffer from bottleneck problem

ADMME: autonomous and distributed MME[1]

- Load balancing in the control plane
  - Mobile management function is distributed over eNodeBs, SGWs, PGWs as a logical function



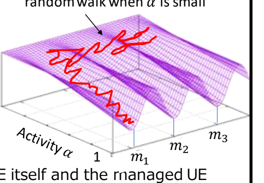
  - ADMME selection
    - Each ADMME manages user equipment (UE) and dynamically determines whether or not to delegate mobility management of the UE to another ADMME considering the load balancing and delay reduction

[1] H. Yang, N. Wakamiya, M. Murata, T. Iwai, and S. Yamano, "An autonomous and distributed mobility management scheme in mobile core networks," in Proc. BICT, Dec. 2015.

ADMME selection mechanism

- Attractor selection algorithm[2]
  - Each ADMME periodically updates state vector $\mathbf{m}$ using a dynamics that has M attractors

$$\frac{\mathrm{d}\mathbf{m}}{\mathrm{d}t} = \alpha f(\mathbf{m}) + \boldsymbol{\eta}$$



- $\mathbf{m} = [m_1,\ m_2,\ m_3, \dots, m_M]$
  - m_i: How good to select ADMME i
  - M: #(candidate ADMMEs)
    - ADMMEs in all nodes on the path between ADMME itself and the managed UE
    - ADMMEs in the nearest SGW and PGW
- $\boldsymbol{\eta}$: Gaussian noise
- α: activity function that reflects goodness of the current $\mathbf{m}$
  - By designing α to associate system performance, this algorithm has adaptability to changing environment

[2] A. Kashiwagi and I. Urabe, "Adaptive response of a gene network to environmental changes by fitness-induced attractor selection," PLoS One, vol. 1, no. 1, pp. e49:1–10, Dec. 2006

Design of activity α

- α is designed for multi-objective optimization[1]
  - to minimize delay between UE and ADMME

$$\alpha_d(h) = \left(\frac{\sum_{k=1}^{W} \frac{\bar{d}_{cm}(h-k)}{k}}{\max_{1\le i\le M} \sum_{k=1}^{W} \frac{\bar{d}_i(h-k)}{k}} \right)^{\epsilon}$$

  - to balance #(managed UE) among all candidate ADMMEs

$$\alpha_l(h) = \frac{\min_{1\le i\le M} l_i(h)}{l_{cm}(h)}$$

  - integrate the above two activity function

$$\alpha(h) = \rho \cdot \alpha_d(h) + (1-\rho)\cdot \alpha_l(h)$$

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when delay is minimized, α_d becomes 1

  - to balance #(managed UE) among all candidate ADMMEs

$$\alpha_l(h) = \frac{\min_{1\le i\le M} l_i(h)}{l_{cm}(h)}$$

when complete LB is achieved, α_l becomes 1

  - integrate the above two activity function

$$\alpha(h) = \rho \cdot \alpha_d(h) + (1-\rho)\cdot \alpha_l(h)$$

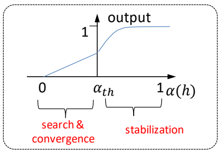
ρ is 0 to 1

Problem

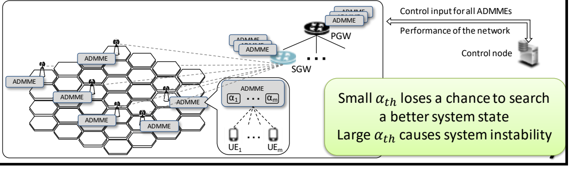
- Both α_d and α_l do not become 1 at the same time
  - * with small α, ADMME frequently switches UE (ADMME switching)
- α has to be nearly 1 in any situation to stabilize the system

Design of new activity α'

- New activity α' with an extended sigmoid function
  - $\alpha'(h) = \max(\alpha(h),\ \sigma(\alpha(h)))$
    - $\sigma(\alpha(h)) = \frac{1}{1+e^{-g(\alpha-\alpha_{th})}}$

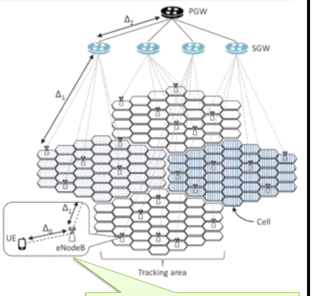


  - Decision of threshold α_{th}
    - Observation and control loop by a control node



Evaluation scenario

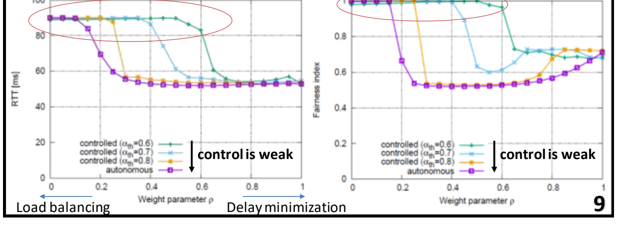
- Network model
  - 1 PGW
  - 4 SGWs/PGW
  - 37 cells (eNodeBs)/SGW
  - 100 UE/cell (total: 14400)
- ADMME selection
  - 5 ADMMEs/SGW, PGW
  - 1 ADMME/eNodeB
  - selection is conducted when receiving the below requests
    - tracking area update request (/30 min)
    - handover request
- Mobility pattern
  - All UE moves to one of neighboring cell every 100 min (random walk pattern)



Delay between two nodes is static in our simulation
Δ0: 2 ms (UE to eNodeB)
Δ1: 20 ms (eNodeB to SGW)
Δ2: 3 ms (SGW to PGW)

Evaluation results
(Response delay and fairness index)

- Mobility pattern: random walk
  - Attractor selection algorithm leads the system state to satisfy delay minimization and load balancing
    - Much UE connect to ADMMEs in eNodeB via SGW or PGW (RTT between UE to ADMME is 88 or 94 ms)
    - Management load is balanced well



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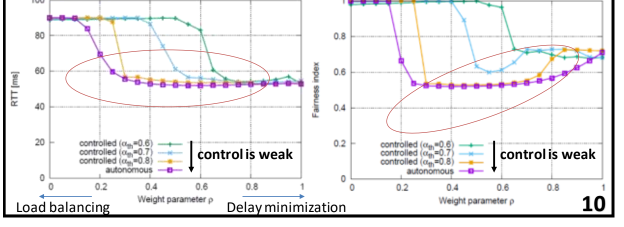
Evaluation results
(Response delay and fairness index)

- Mobility pattern: random walk
  - Attractor selection algorithm leads the system state to satisfy delay minimization and load balancing
    - More UE connect to ADMMEs in SGW and PGW (In this case, RTT is 44 or 50 ms)
    - Fairness decreases as the load of SGW and PGW increases



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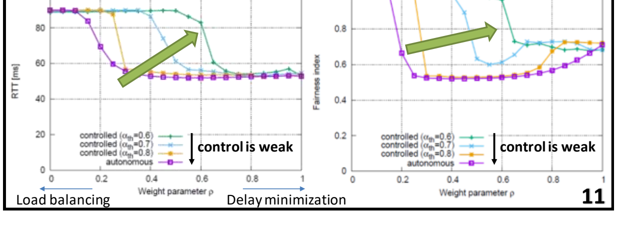
Evaluation results
(Response delay and fairness index)

- Mobility pattern: random walk
  - Using threshold value α_{th} can control the characteristics in performance
  - Threshold value is set to obtain good performance in addition to the control-plane load
    - We have to consider the number of ADMME switching



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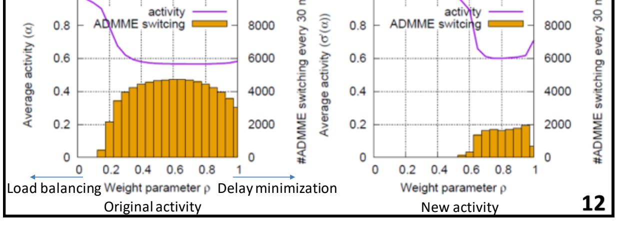
Evaluation results
(ADMME switching)

- Mobility pattern: random walk
  - α_{th} is set to 0.6 (fixed)
  - Original activity α has more difficulty to become 1 comparing to the static pattern
  - Since stabilization makes delay longer when UE moves, α' becomes small with large ρ



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Conclusion

- Conclusion
  - We propose a simple control method for controlling both of the network stability and performance in an autonomous system for the 5G mobile and wireless communication system
  - Reduction in the delay and the overhead of the control plane in the 5G network can be realized
- Future work
  - Further evaluation of the threshold control in activity function
  - Another application of our proposal, such as a mobile edge computing scenario