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Predictive traffic engineering incorporating real-world information inspired by the cognitive process of the human brain

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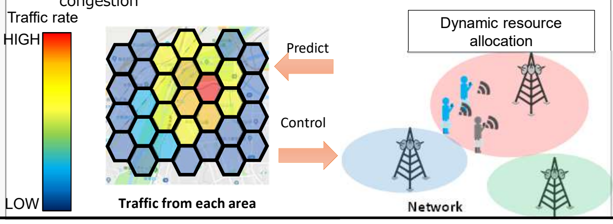
Background

- **The time variation of Internet traffic becomes large.**
  - Growth of the Internet services such as streaming, cloud service, etc
  - When traffic fluctuates greatly, it is necessary to accommodate traffic avoiding congestions.
- **Predictive Traffic Engineering (TE)**
  - Dynamically allocate resources based on predicted demands to avoid congestion



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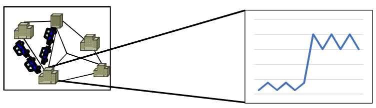
Prediction of future demand

- **Time series analysis of past traffic cannot achieve accurate prediction.**
  - Traffic may change differently from the past traffic fluctuations.
- **Real-world information may be helpful to achieve accurate prediction**
  - E.g., the traffic from the area where may people are going will increase



- **Problem to use real-world information: Relation between future demand and the real-world information is unclear.**

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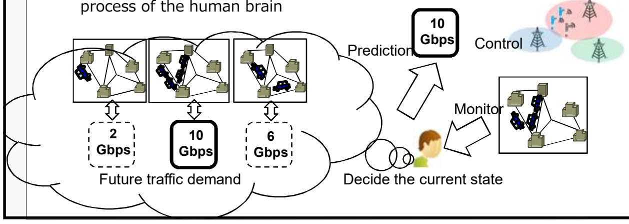
Goal and approach

- **Goal: Accurate predictive TE using real-world information**
- **Approach:**
  - Define the states of the network by using the monitored information.
  - Calculate the required resourced to be allocated for each state
  - Decide the current state by using the method inspired by the cognitive process of the human brain



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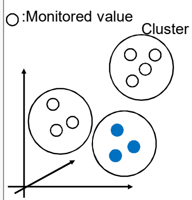
Define of states

- **Define the state by clustering**
  - Each cluster includes the similar monitored information.
  - Each cluster define a state



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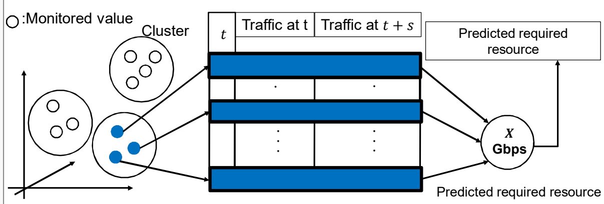
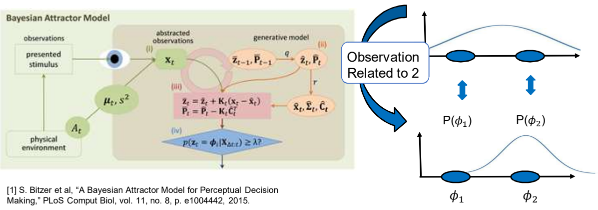
Allocate required resources

- **Assign the required resource to each cluster as the maximum future traffic volume of the data included in the cluster**



Bayesian Attractor model [1] (BAM)

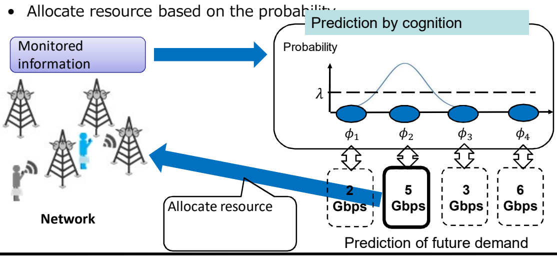
- **Model of the process by which the brain makes decisions based on uncertain sensing information**
  - The BAM encodes the predefined options and makes decisions depending on the option of the current status
  - The decisions are made by updating the decision state every time the observations are obtained by inverting the generative model using Bayesian inference



[1] S. Bitzer et al, "A Bayesian Attractor Model for Perceptual Decision Making." PLoS Comput Biol, vol. 11, no. 8, p. e1004442, 2015.

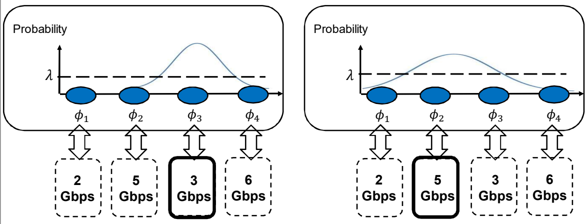
Predictive TE inspired by the cognitive process of the human brain

- **Training phase**
  - Define state by the monitored information including real-world information
  - Define future required resources for each state
- **Control Phase**
  - Obtain the probability of the current state
  - Allocate resource based on the probab...



Resource allocation based on probability

- **Select states whose probabilities exceed a threshold λ**
- **Allocate maximum resources among the selected states**



Evaluation

- **Data**
  - Real-world information: pseudo-generated GPS trajectory dataset [2]
  - Traffic from each user: generated by the traffic simulator [3]
- **Area**
  - Defined by artitioning Chiyoda-ku, Tokyo, into areas of 0.0036 (about 350 m) in both latitude and longitude.
- **Predicted time slot for resource allocation**
  - Predict the amount of future traffic 40 minutes in advance to allocate resources
- **Monitored information**
  - Traffic volume from/to each area
  - Number of users in each area

[2] T. Kashiyama, Y. Pang, and Y. Sekimoto, "Open pflow: Creation and evaluation of an open dataset for typical peo- ple mass movement in urban areas," Transportation Re- search Part C: Emerging Technologies, vol. 85, pp. 249–267, 2017.

[3] E. M. R. Oliveira, A. C. Viana, K. P. Naveen, and C. Sar- raute, "Measurement-driven mobile data traffic modeling in a large metropolitan area," in Pervasive Computing and Communications (PerCom), 2015 IEEE International Conference on, pp. 230–235, IEEE, 2015.

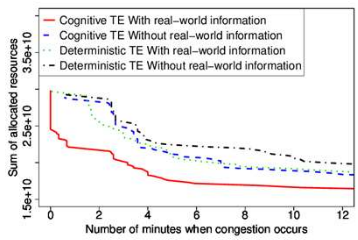
Metric and compared methods

- **Metric**
  - Required amount of resources so as to make the number of time slots in which congestion occurred less than a threshold
- **Compared method**

Name	Used information	Method to determine
Cognitive TE with real-world information	Traffic volume and number of users	Inspired by cognition process of brain
Cognitive TE without real-world information	Traffic volume only	Inspired by cognition process of brain
Deterministic TE With real-world information	Traffic volume and number of users	Use only the current information
Deterministic TE With- out real-world information	Traffic volume only	Use only the current information

Result

- **The cognitive TE with real-world information required a smaller amount of resources to mitigate congestion**
  - Because the real-world information enables us to capture the difference in the states which could not be distinguished by using only traffic volume information
  - Because the cognitive TE with real-world information controls the traffic based on confidence, and avoid risks to congest.



Conclusion

- **We proposed a predictive traffic engineering method that predicts future traffic by using information monitored in the real world.**
- **The results demonstrated that our method avoids congestion without requiring a large amount of additional resources**
- **Future work**
  - Optimize of the parameter settings of our method
  - Evaluate our method in a different environment