Traffic Engineering

- Increasing the time variation of traffic in a backbone network
- Deployment of streaming, cloud services, etc.
- Traffic Engineering (TE)
- Periodical measurement of traffic and optimization of routes

Bayesian Decision Making

- Decision making of brain under uncertainty
  - Estimates/Predicts state based on observation
  - Decides action with a certain confidence

Bayesian Framework for TE

- Collected Data: \( X_t \)
- Data Selection
- Data Request
- Route: \( R_{t+1} \)
- Controller
- Estimated Distribution: \( P(X_t) \)
- Distribution: \( P(X_{t+1}) \)
- Decision Maker
- Prediction
- Estimated Distribution: \( P(X_{t+1}) \)
- Predictor
- Decision Maker

Difficulty in Integration

- Direct/Indirect interactions among different processes
  - Estimation accuracy directly depends on which data is monitored
  - Route decision indirectly depends on which data is monitored
  - etc.

- Only partial integrations in previous work
  - Traffic estimation and monitoring
  - Traffic prediction and route decision

Uncertainty of Traffic Information

- Causes of uncertainty
  - Lack of observation
  - Lag between observation and control

- Existing technology against the uncertainty in TE
  - Traffic monitoring
  - Stochastic/Robust route decision
  - Traffic estimation
  - Traffic prediction

Integration of whole processes has not been achieved


Increasing the time variation of traffic in a backbone network


There is some uncertainty of traffic information.
Estimator

- **Role**
  - Estimating current traffic from partial data and previous prediction
  
  \[ x_t = \text{data} \]

- **Calculation**
  \[ P(x_t|x_t, O_t) : \text{estimation} \]

- **Estimator**
  - Data collection method
  - Prediction result at \( t = 1 \)

- **Likelihood**
  - Prior distribution (from data)
  - Posterior distribution

Predictor

- **Role**
  - Estimating current traffic model which current traffic pattern follows
  - Predicting next traffic using model and estimated current traffic

- **Calculation**
  \[ P(x_t'|x_t', O_t) \]

- **Predictor**
  - Model estimation:
    \[ P(x_t'|x_t', O_t) = \sum_{x_t} P(x_t|x_t', O_t) P(x_t') \]

- **Decision Maker – Route Decision**
  - Setting routes to accommodate predicted traffic including errors
  - Keeping the probability of congestion lower than \( p \) by SMP-TE

- **Calculation**
  \[ \min \left\{ \sum_{\text{routes}} \left[ (1 - w) \mathbb{I}(x_t, R_t) + w \| \Delta R_t \|^2 \right] \right\} \]

- **Decision Maker – Data Selection**
  - Deciding which data to collect at next time
  - Considering how the new data affects on other processes

- **Calculation**
  \[ \min \left\{ \sum_{x_t} P(x_t|x_t', O_t) \right\} \]

Summary and Future work

- **Summary**
  - Problem of existing approach in TE
  - Traffic uncertainty is separately tackled by different processes
  - Integrating the different processes is not completely achieved
  - Our proposal
  - Establishing a Bayesian framework of TE to handle the uncertainty
  - Considering how the decision affects the other processes in decision making

- **Future work**
  - Implementing the proposed framework with particular methods
  - Especially data selection
  - Evaluation for the effectiveness of the proposed framework