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Robust Virtual Network Topology Control based on Attractor Selection

Needs to a robust network control against environmental changes

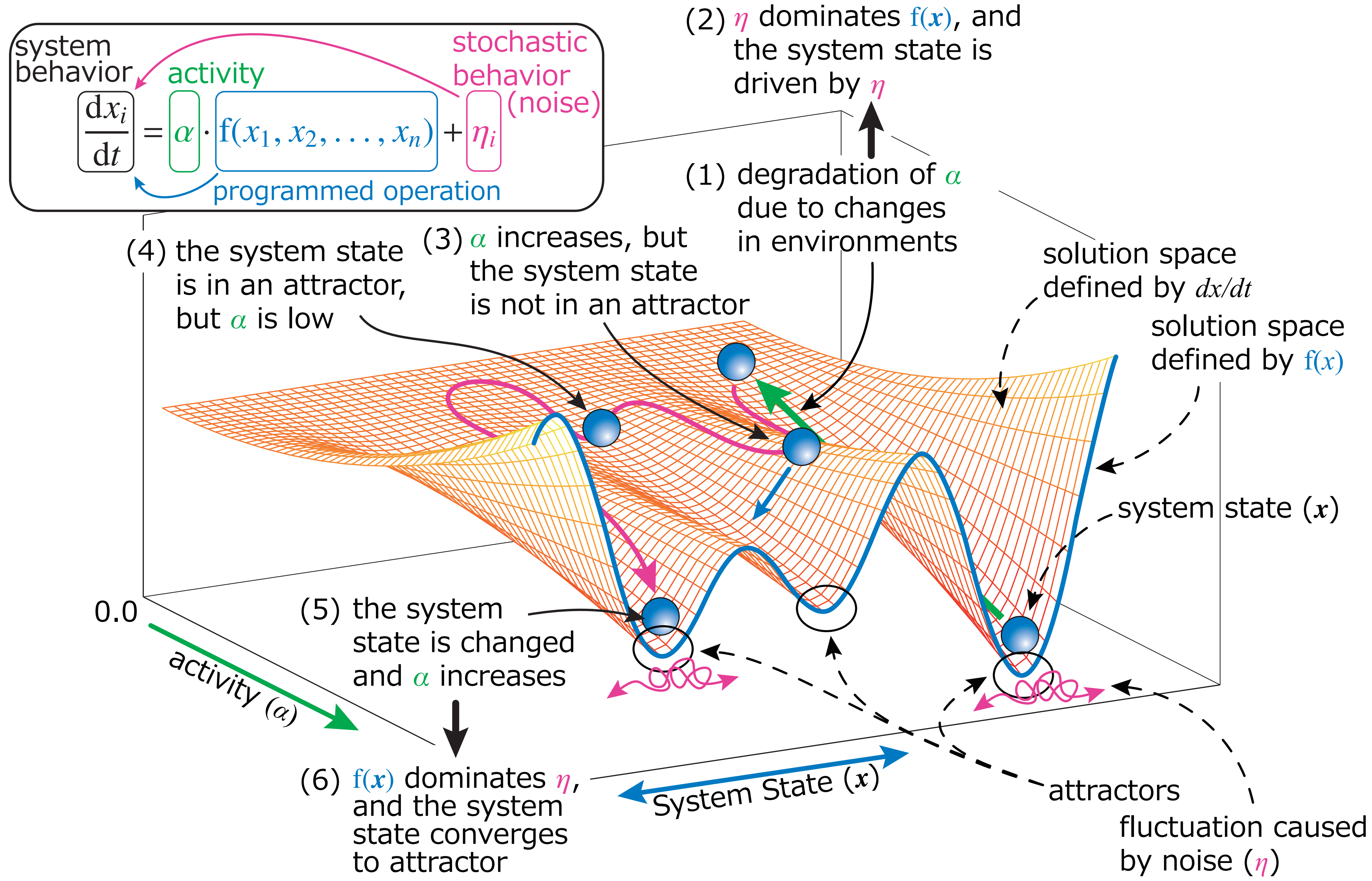
- Large environmental changes
  - e.g., Interactions between traffic engineering and overlay routing
- Various environmental changes
  - Changes in traffic
  - Link failures

To achieve an robust VNT control to various environmental changes,
→ we focus on attractor selection.

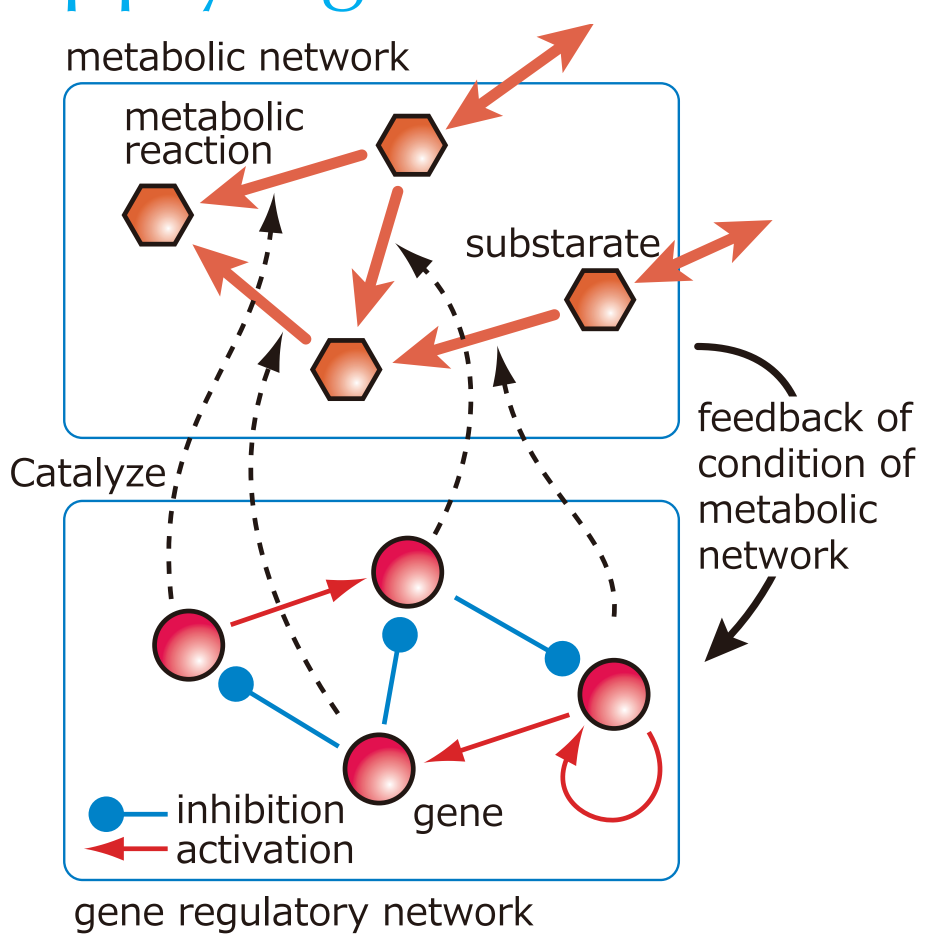
Attractor selection

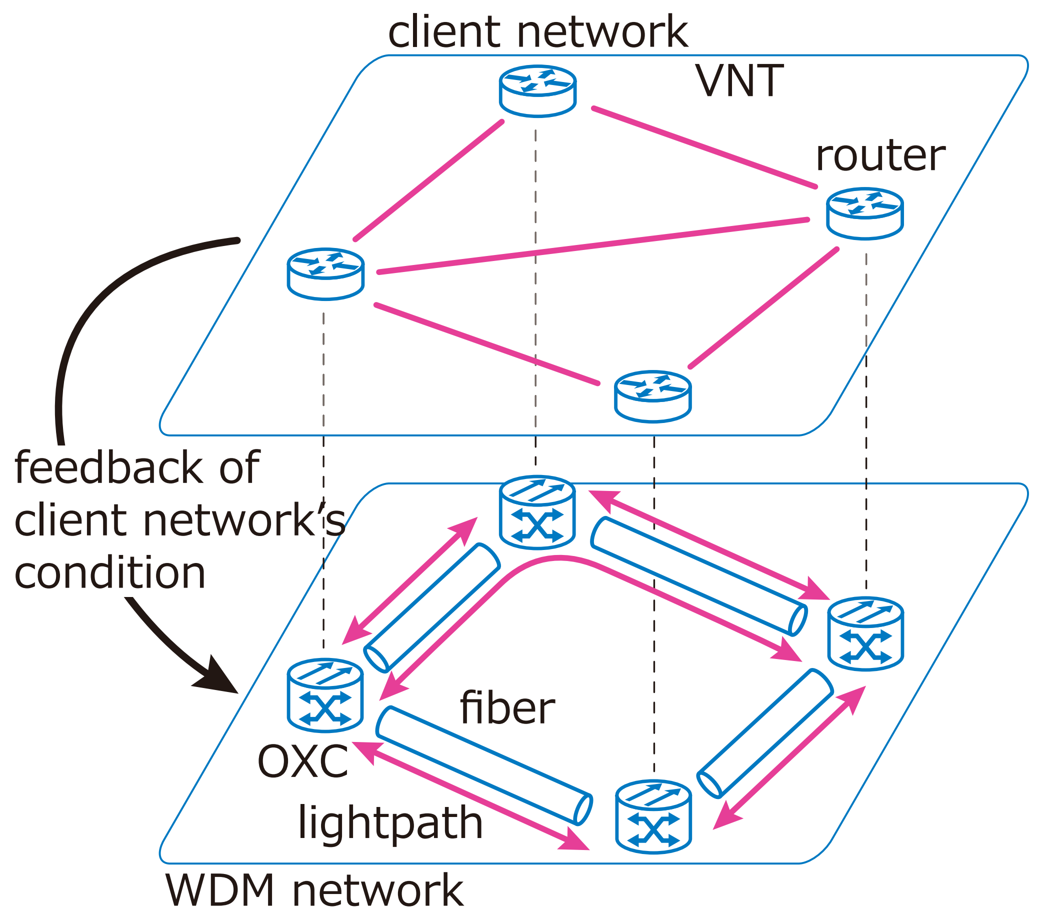
- Models for explaining adaptability of biological systems
  - E.coli cell, gene-metabolic network
- Fundamental elements of attractor selection
  - Noise
  - Programmed operation
  - Activity (Condition of the system)

Basic behavior of attractor selection



Applying attractor selection model in gene-metabolic network to VNT control





Condition	Gene-matabolic network	WDM network
Poor (= low activity)	Search for other attractor where system condition is better by noise	Search for other VNTs that accommodate client network's traffic better by noise
Good (= high activity)	Converge to the attractor	Converge to the attractor
Mechanism	The gene regulatory network controls the metabolic network adaptively to environmental changes	The WDM network controls client network adaptively to environmental changes

Achieve adaptability to environmental changes by using the noise and the feedback of the condition of the client network

VNT control based on attractor selection

expression levels (for determining number of lightpaths)

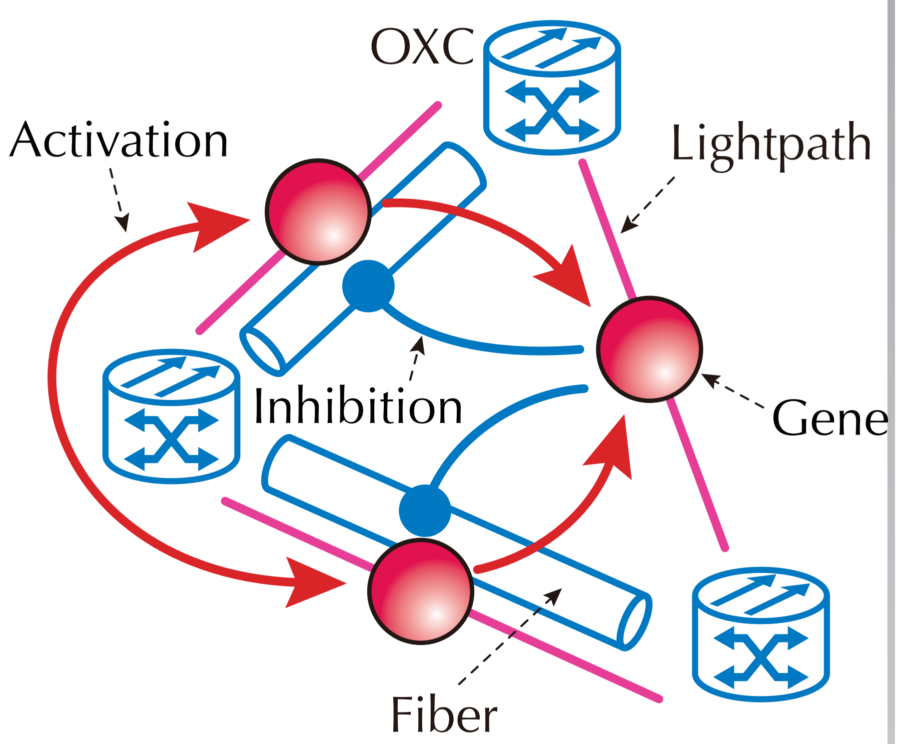
programmed operation   noise

$$dx_{p_{ij}}/dt = \alpha \cdot \left\{ \mathrm{sig}\left(\sum_{p_{sd}} W(p_{ij}, p_{sd}) \cdot x_{p_{sd}} - \theta_{p_{ij}} \right) - x_{p_{ij}} \right\} + \eta$$

system behavior   activity   interaction of genes (activation/inhibition)

- Place genes to all node pairs (p_{ij})
- Determine number of lightpaths on p_{ij} by the expression level (x_{pij}) on p_{ij}
  - Large x_{pij} → Many lightpaths
  - Small x_{pij} → Few lightpaths

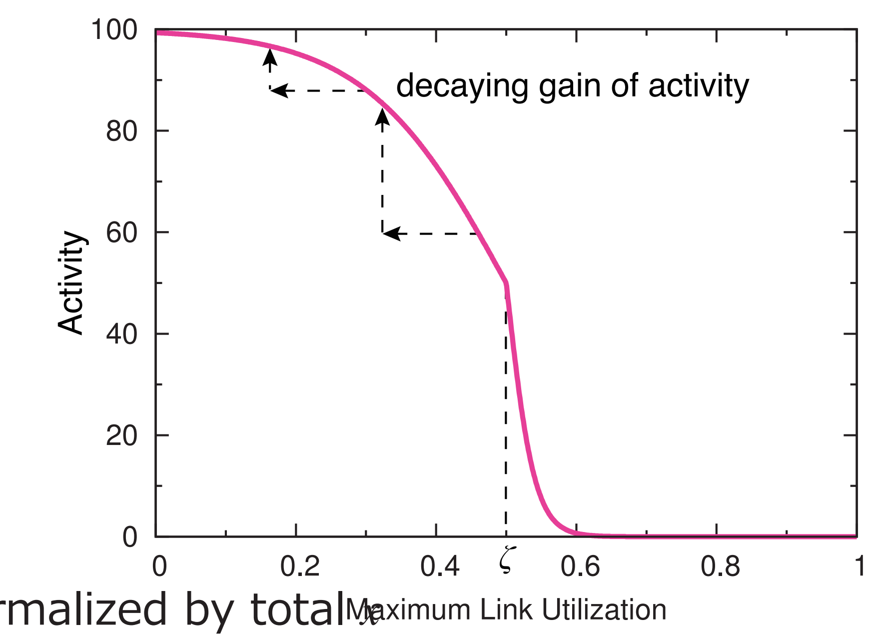
Policies to design attractors



- Attractors are defined by activation/inhibition between genes
  - Represented by $W(p_{ij}, p_{sd})$
  - p_{ij} activates p_{sd} → increases x_{psd} → increases the number of lightpaths on p_{sd}
  - p_{ij} inhibits p_{sd} → decreases x_{psd} → decreases the number of lightpaths on p_{sd}
- Encode the motivations to set up or tear down lightpaths
  - Adding lightpaths for effective transport of traffic → Activation
  - Establishing lightpaths for detouring traffic → Activation
  - Decreasing lightpaths due to resources being shared with other node pairs → Inhibition

Activity

- Condition of the client network
  - The maximum link utilization (u_{max}) of the client network
  - Other metrics can be used



VNT construction

- Assign resources in the WDM network according to x_{pij}
- A fixed amount of noise has a constant influence on our method
  - Applying hysteresis to avoid unnecessary VNT reconfigurations

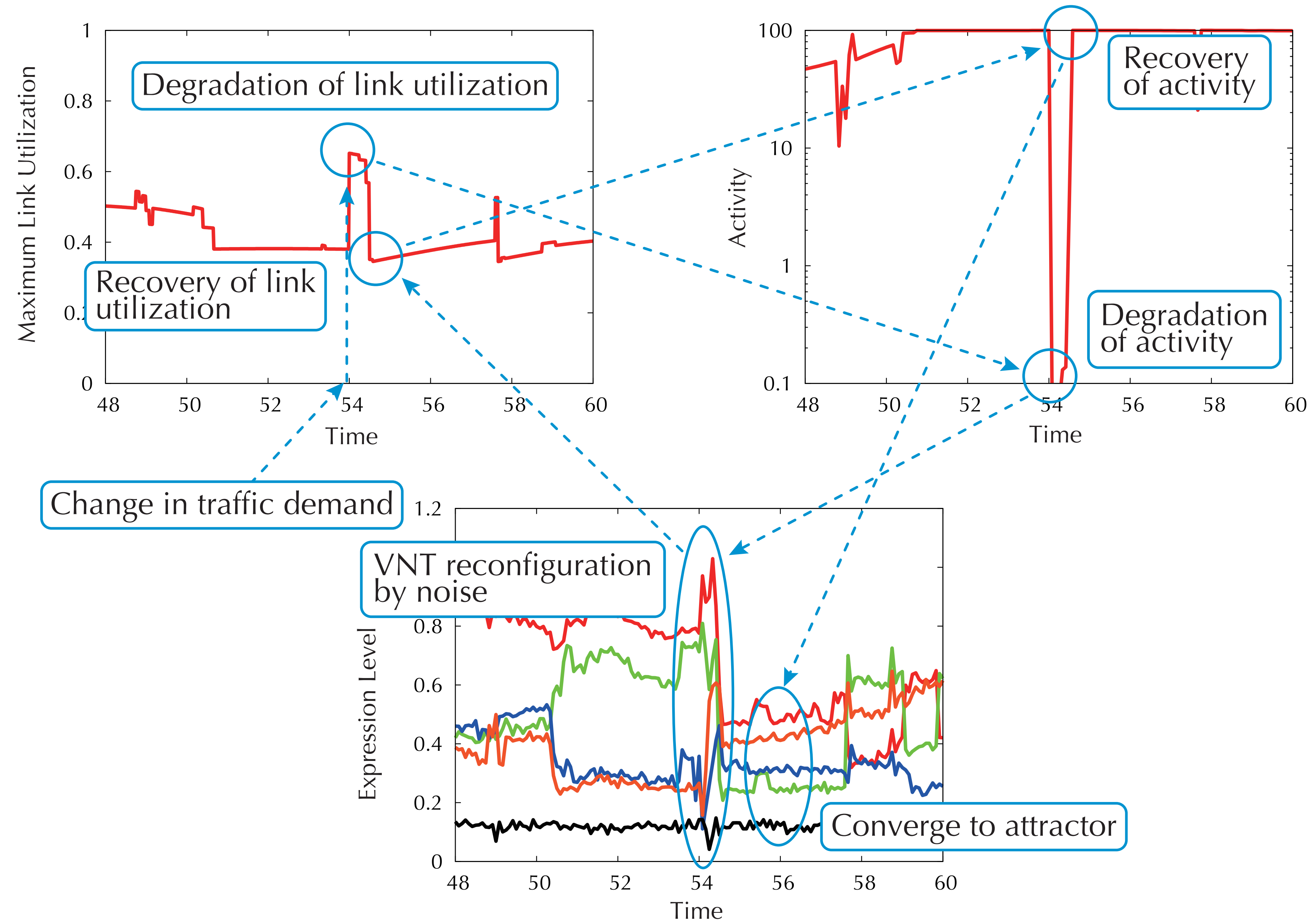
$x_{p_{ij}}$ normalized by total for all the node pairs that use the receiver on node j

convert to integers by the floor function

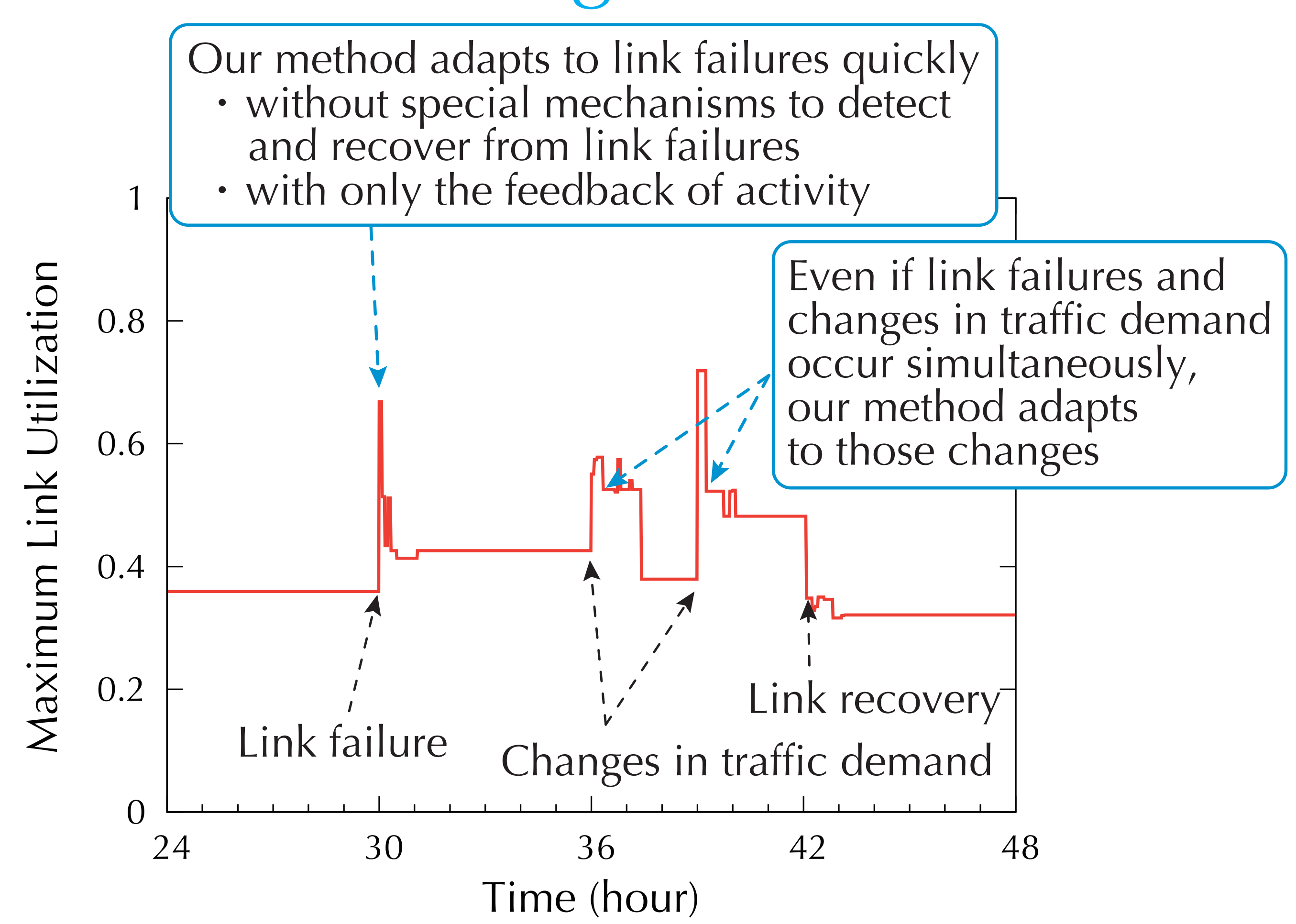
$$G_{p_{ij}} = \min\left(\left\lfloor P_R \cdot \frac{x_{p_{ij}}}{\sum_s x_{p_{sj}}} \right\rfloor, \left\lfloor P_T \cdot \frac{x_{p_{ij}}}{\sum_d x_{p_{id}}} \right\rfloor \right)$$

satisfy the constraints of both receivers and transmitters

Behaviors of VNT control based on attractor selection



Robustness against various environmental changes



Future work

- To find appropriate amplitude and type of the noise for VNT control