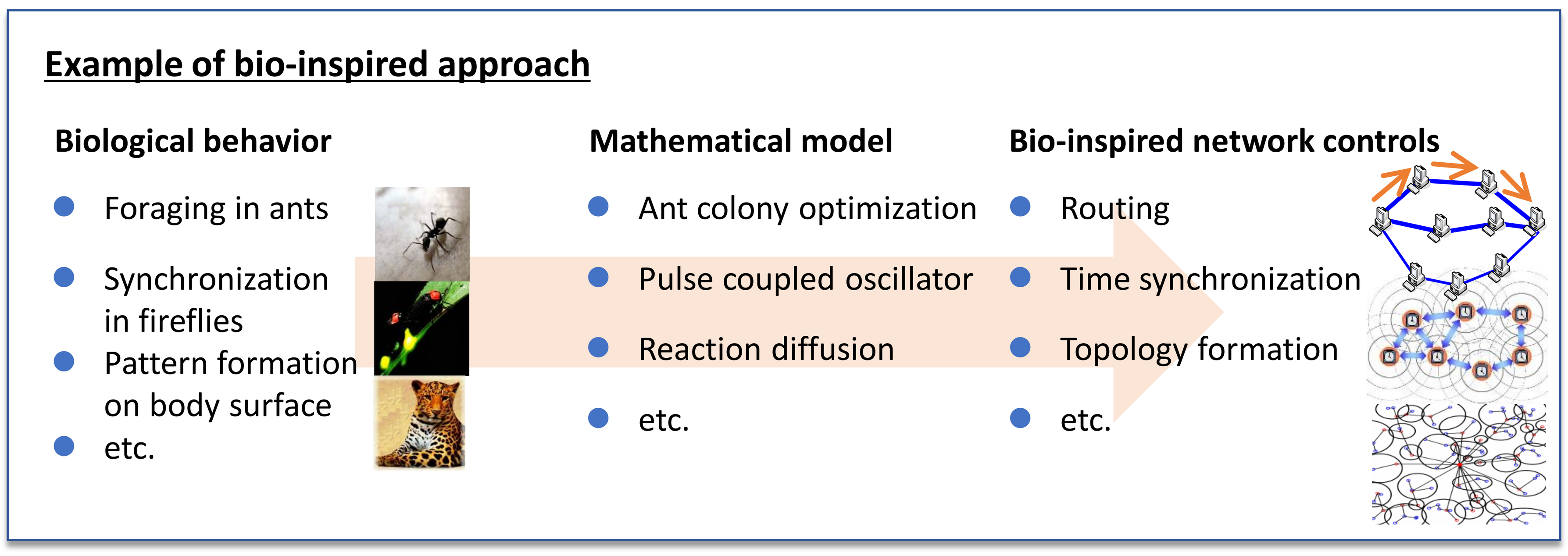
THERMODYNAMICS-BASED ENTROPY ADJUSTMENT FOR ROBUST SELF-ORGANIZED NETWORK CONTROLS

Takuya IWAI, Daichi KOMINAMI, Masayuki MURATA, Tetsuya YOMO

Background and objective of our research

Expectations for biological self-organization-based network controls

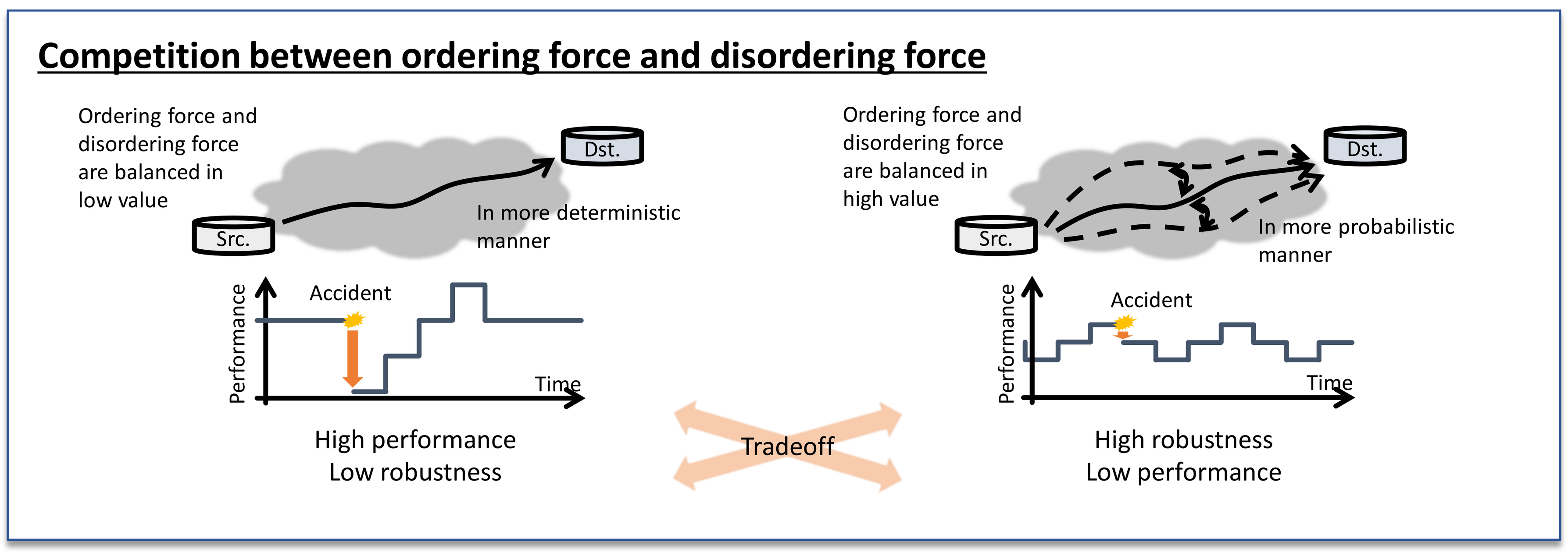
- Information network must be more robust against ever-increasing dynamics & complexity.
- Many researchers are actively working on self-organization-based network controls.
- Many successful attempts published in literatures show their usefulness[1].



[1] F. Dressler and O. B. Akan, "A survey on bio-inspired networking," Computer Networks, vol. 54, pp. 881–900, Apr. 2010.

Difficulty in simultaneously achieving robustness and performance

- Self-organization-based network controls are driven by the competition between their ordering force(a) and disordering force(b).
- If the appropriate balance between both forces is achieved, we can realize excellent network controls which simultaneously achieve high performance and robustness.



(a) **Ordering force** makes a network control change its state toward a better state, and this force makes a significant contribution for achieving high performance.

(b) **Disordering force** makes a network control changes its state veer an unintended state, and this force plays an important role in achieving high robustness, which is a feature to prepare for unexpected failures, e.g. node failures.

Question

How do we determine the balance between ordering force and disordering force?

Thermodynamics-based entropy adjustment

Idea: we focus on thermodynamic phenomenon where substances achieve good balance between its ordering & disordering force depending on its temperature

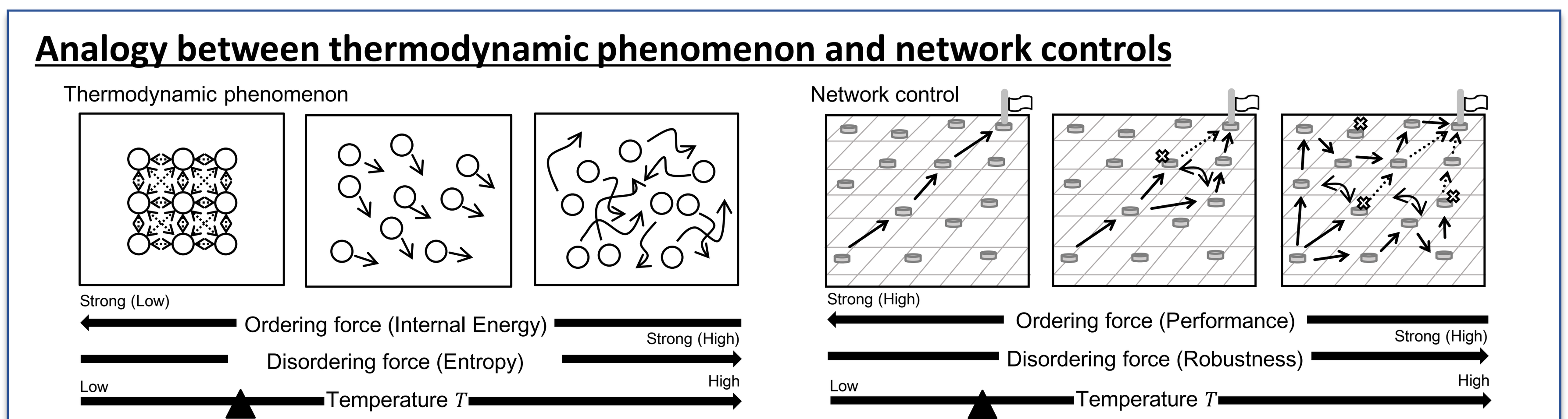
- Substances change their state as follows:

Ordering force — Disrdering force — Parameter to determine the balance

$$\Delta A = \Delta E - \Delta S \, T < 0$$

If high temperature, $\Delta S > 0$ is effective to $\Delta S < 0$
If low temperature, $\Delta E < 0$ is effective to $\Delta S < 0$

Symbol	Description
Internal energy E	Variability of a substance's internal structure.
Entropy S	Randomness of a substance's internal structure.
Temperature T ($T = \Delta E/\Delta S$)	Parameter to determine balance between ΔE and ΔS
Free energy A	Badness of balance between ΔE and ΔS

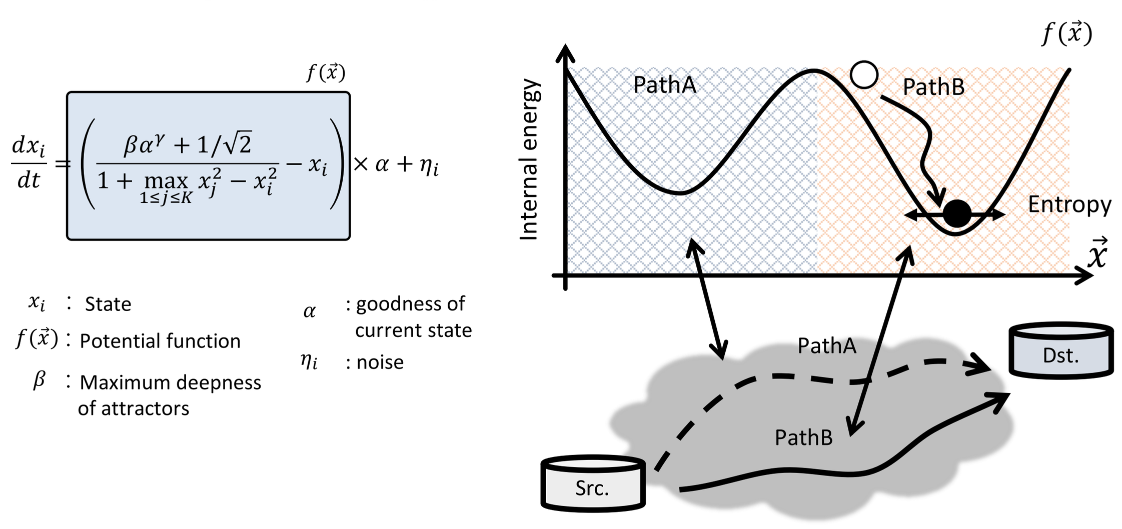


Temperature determines balance between ordering force and disordering force

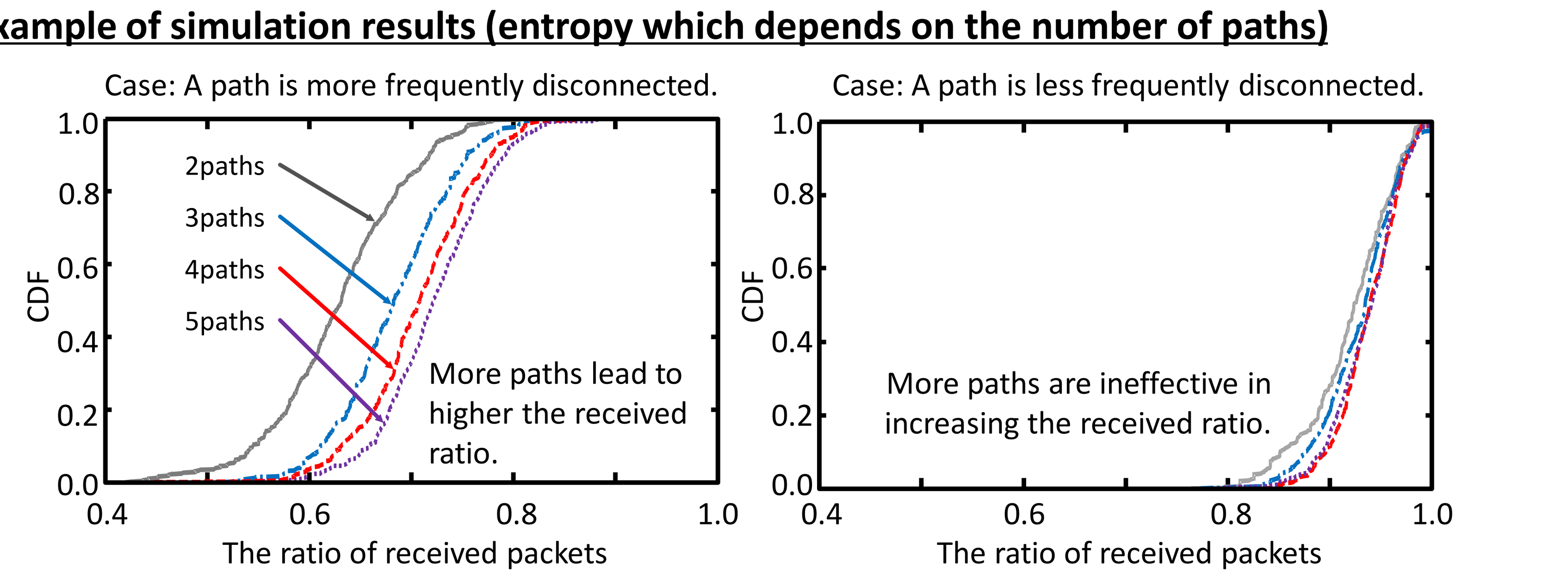
If we determine appropriate temperature of a network control depending on its requirements, we can simultaneously achieve appropriate robustness and performance.

Verification of our approach taking a multi-path routing as an example of network controls

- We show that appropriate entropy S exists depending on network conditions.



Deepness of attractors and the number of attractors affect entropy S.



These figures shows that the appropriate number of paths (=entropy) is determined depending on the environmental condition (=temperature).

[2] K. Leibnitz, N. Wakamiya, and M. Murata, "Biologically inspired self-adaptive multi-path routing in overlay networks," ACM Communications, vol. 49, pp. 62–67, Mar. 2006.