Future Mobile Network Management With Attractor Selection

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Gen Motoyoshi [*] [†], Naoki Wakamiya [†], Masayuki Murata [†]
[*] NEC Corporation , [†] Osaka University

Background

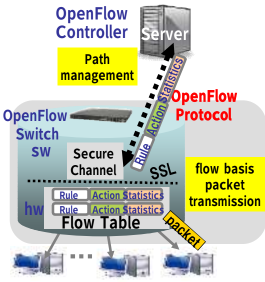
- Research on future Internet is too numerous to mention
  - NSF (USA), FP7 (Europe), AKARI (Japan), …
  - Clean slate approach due to current Internet limitations
- Important requirements for the future Internet from AKARI activity
  - Large capacity: Peta-bps class backbone NW, …
  - Scalability: 100 billion devices, M2M communications
  - Robustness: Essential services (medical care, transportation, emergency services), 99.99% reliability
  - Safety: Privacy, banking services, food supply, …
  - Energy efficient: Ecology and sustainable society
  - Ubiquity: Monitoring of global environment and human society

Efficiency / Reliability / Mobility

Efficient and Reliable System including **Mobility** Functions is Essential

Problem Statement and Proposal Summary

- **OpenFlow** is a promising technology for the future Internet
  - Programmable and software defined network per user basis
  - ↑ flexible path management
  - ↓ signaling cost or scalability issue
  - Centralized control configuration
  - ↓ possibility of single point of failure
- **Attractor selection** is a promising mechanism robust against environmental changes

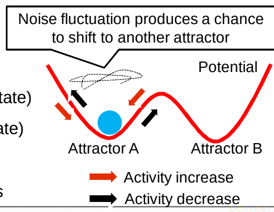


We propose an extension of attractor selection onto OpenFlow network for the future mobile network design

Attractor Selection Mechanism

- Biologically-inspired self-adaptive control mechanism
  - Simple selection mechanism with feedback-controlled randomness
  - Accurately attractor-based selection and randomly noise-based selection at the same time
  - Robustness against the external fluctuations
- Model: $$\frac{d\vec{m}}{dt} = f(\vec{m})\cdot\alpha + \vec{\eta}$$

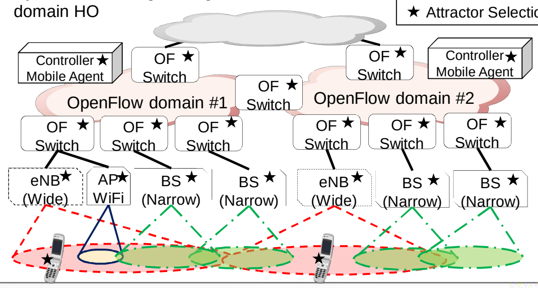
α : Activity (goodness of the current state)
$\vec{\eta}$: Noise (randomness for a better state)
$\vec{m}$: State (candidates for selection)
$f(\vec{m})$: Potential function for the states



Future Mobile Network w/ Attractor Selection

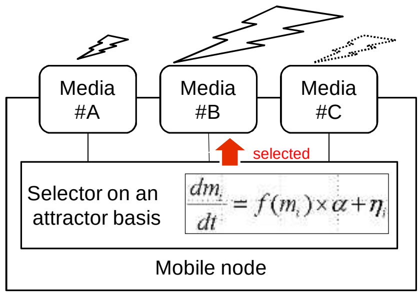
- Attractor selection mechanism is adapted to OpenFlow network for future mobile network
  - Best radio interface selection in multi-mode MN
  - Dynamic clustering management to alleviate inter-domain HO

OF Switch: OpenFlow Switch
eNB: enhanced NodeB
BS: Base Station
AP: Access Point
★ Attractor Selection



(1) Best Radio Interface Selection Image

- The best radio interface on the current condition is selected according to the attractor selection equation



(1) Best Radio Interface Selection Model

$$\frac{dm_k}{dt} = f(m_k) \times \alpha + \eta, \quad 1 \le k \le K$$

$$\frac{dm_{j,k}}{dt} = \frac{s(\alpha)}{1 + \max(m_{1,k},\dots,m_{M,k})^2 - m_{j,k}^2} - d(\alpha) m_{j,k} + \eta, \quad j = 1,\dots,M$$

$$s(\alpha) = \alpha\left(\beta\alpha^{\gamma} + 1/\sqrt{2}\right), \quad \mathrm{d}(\alpha) = \alpha$$

$$\alpha = \begin{cases} \dfrac{1}{1+\exp(-G \cdot \overline{Q})} : (\overline{Q} > 0) \\ 0 : (\overline{Q} = 0) \end{cases}$$

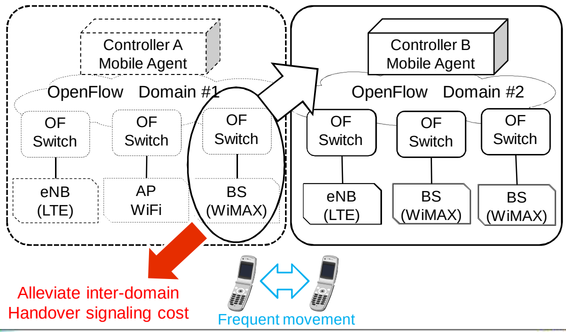
Best interface is selected based on statistics of real-time link quality

$$\boxed{\overline{Q} = \left(\left\{ \sum_{i=1}^{P_1} W_i (Eb/No)_i \right\} / P_1 / (Eb/No)_* + \left\{ \sum_{k=1}^{P_2} W_k (BW)_k \right\} / P_2 / (BW)_* \right) / 2}$$

Parameter	Content
k	Media interface type
$M_{j,k}$	Evaluation value (probability) for each access media “k” on device “j”
Beta, Gamma	Control parameters
Q	Satisfaction degree against condition
Eb/No	Real-time traffic amount per single bit energy
Eta	Noise = natural AWGN (Additive White Gaussian Noise)

(2) Dynamic Clustering Management Image

- To change clustering dynamically according to the attractor selection equation in order to reduce signaling cost for inter-domain handover



(2) Dynamic Clustering Management Model

$$\frac{dm_x}{dt} = f(m_x) \times \alpha + \eta$$

$$\frac{dm_{y,x}}{dt} = \frac{s(\alpha)}{1 + \max(m_{1,x},\dots,m_{M,x})^2 - m_{j,x}^2} - d(\alpha) m_{j,x} + \eta, \quad x = 1,\dots,M$$

$$s(\alpha) = \alpha\left(\beta\alpha^{\gamma} + 1/\sqrt{2}\right), \quad \mathrm{d}(\alpha) = \alpha$$

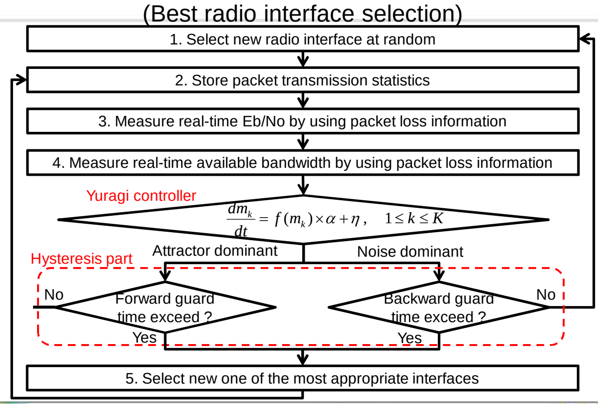
$$\alpha = \begin{cases} 1/\left\{1 + \exp(-G \cdot \overline{R})\right\} : (\overline{R} > 0) \\ 0 : (\overline{R} = 0) \end{cases}$$

Best controller domain to join is selected based on the ratio of control signaling to user traffic

$$\boxed{\overline{R} = \sqrt{\sum_{i=1}^{D} W_i (|N(T_i)/N(C_i)|)^2} / N(T/C)_*}$$

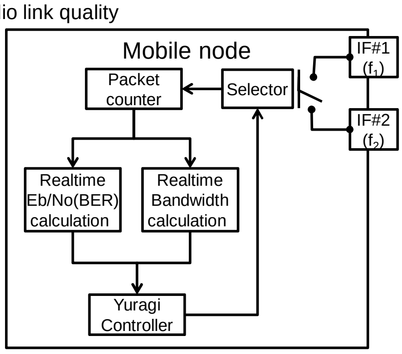
Parameter	Content
m_x	Probability to select Group “x” = OpenFlow controller “x”
$m_{y,x}$	Evaluation value (probability) for each device “y” to belong to “x” Grp
Beta, Gamma	Control parameters
R	Difference ratio between traffic volume on C-ch and T-ch
i	Edge number that the node has
N(T) , N(C)	Traffic volume of T-ch and C-ch
Eta	Noise = AWGN

Selection Algorithm Example
(Best radio interface selection)



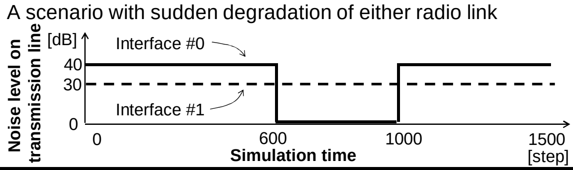
Configuration (Best Radio I/F Selection)

- Equation of the Yuragi controller is driven, based on the real-time radio link quality



Simulation scenario and parameters

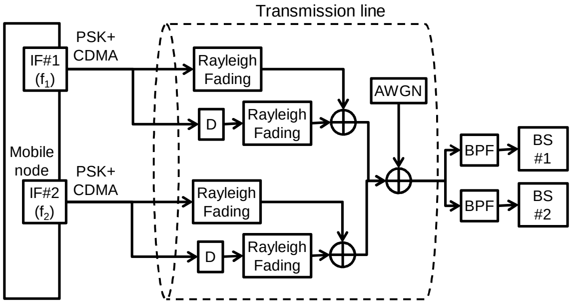
- A scenario with sudden degradation of either radio link



Parameter	Value
Number of radio interfaces	2
Spreading code length	31 chip
Data transmission rate & Chip rate	1 Mbps & 32 Mcps
Data decision method	Maximum likelihood decision (matched filter)
Carrier frequency	20 MHz
Transmission line model	Additive White Gaussian Noise Two path Rayleigh fading (Delay=1chip)
Min. threshold for Eb/No & Bandwidth	10 dB & 100 Hz

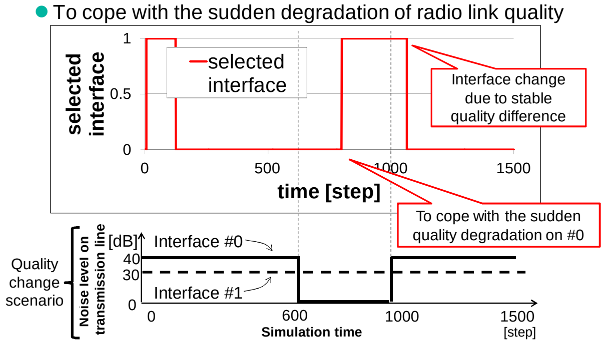
Simulation Model

- Data transmission model with Additive White Gaussian Noise and Multipath Rayleigh Fading on a transmission line



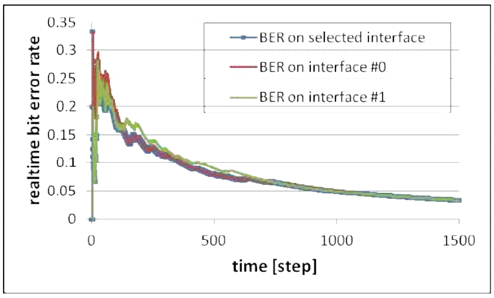
Simulation Results (1)

- Transition of the selected best radio interface
  - To cope with the sudden degradation of radio link quality



Simulation Results (2)

- Transition of Bit Error Rate on each radio interface
  - The interface to have a better BER is selected



Conclusion

- Summary
  - Proposed concepts to adapt attractor selection mechanism into future mobile network
    - To select the best radio interface among several interfaces on one mobile node
    - To formulate the best cluster to alleviate signalling cost for inter-domain handover
  - Evaluations by simulation
    - Our proposed method can cope with a sudden change of radio link quality in case of the radio I/F selection
- Future Work
  - More evaluations on different scenarios