이기종 무선 네트워크에서의 RAT 선택 및 JRRM 기술

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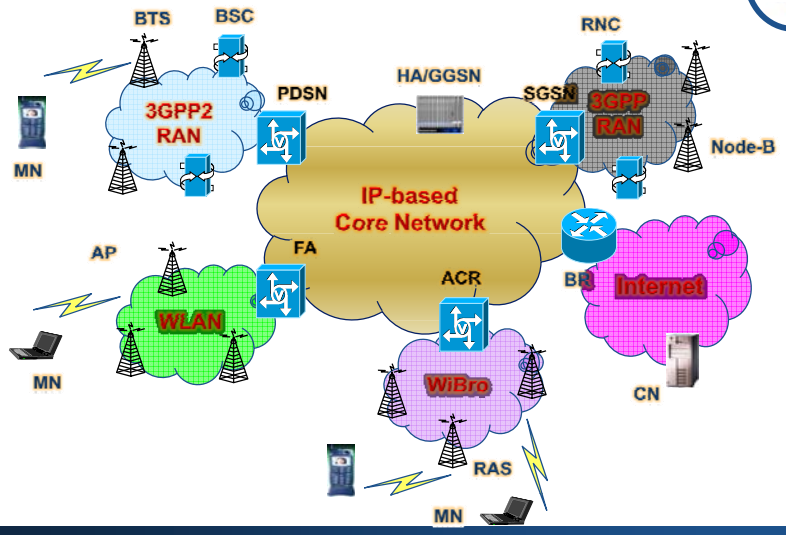
Contents

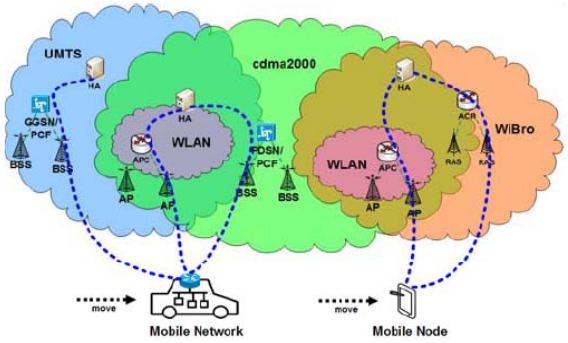
- Joint/Common Radio Resource Management
- Survey on RAT Selection Algorithms
- Preliminary Study on CRRM
- Summary & Future Work

Heterogeneous Wireless Networks



Heterogeneous Wireless Networks (Cont'd)

- Overlaid heterogeneous wireless networks
  - Mobile nodes/networks equipped with multiple interfaces
  - Cognitive radio environment on SDR terminals

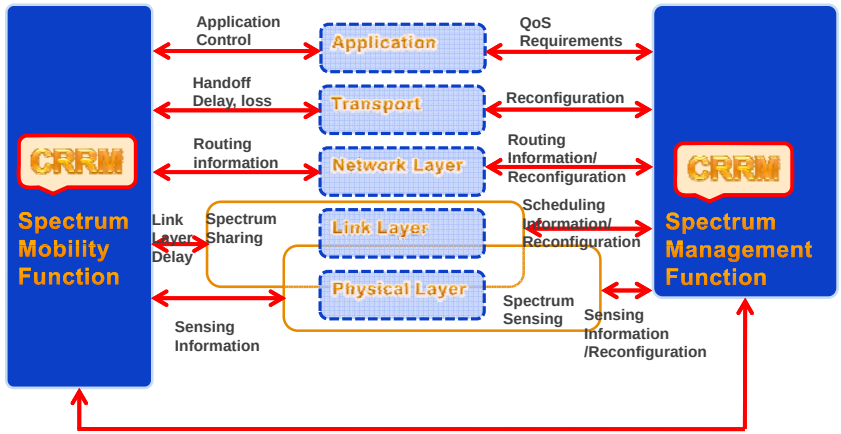


Common Radio Resource Management

- CRRM / JRRM (Joint Radio Resource Management)
  - Jointly manages radio resources among different Radio Access Technologies (RAT) in an optimized way
  - Brings significant benefits such as
    - Load balancing
    - Interference distribution
    - Reduction of unnecessary handovers
    - Reduction of blocking probability
  - CRRM functions
    - Initial RAT selection
    - Vertical handover
    - Common admission control
    - Common congestion control
    - Common packet scheduling

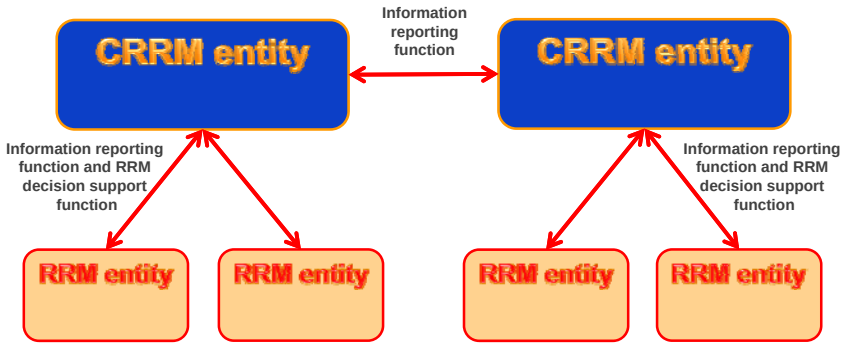
CRRM (Cont'd)

- Cognitive radio communication functionalities



CRRM (Cont'd)

- CRRM interaction model

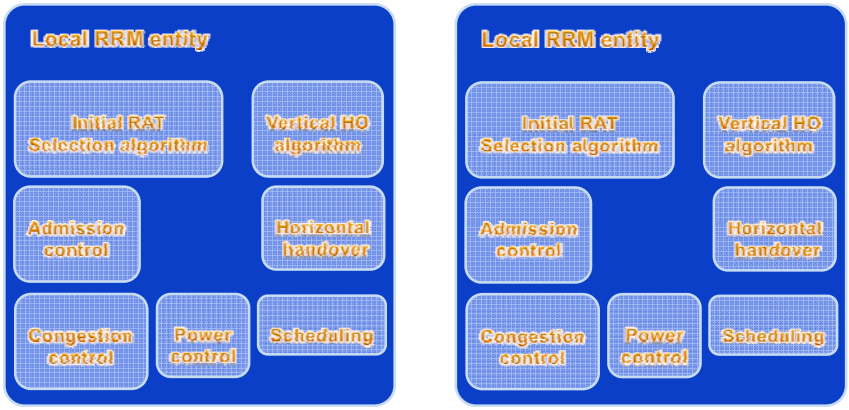


CRRM (Cont'd)

- CRRM interaction model (Cont'd)
  - Information reporting function
    - Static cell information
      - cell relations
      - capabilities and capacities
      - available QoS
      - max. bit rate for a given service
      - avg. buffer delay, etc.
    - Dynamic measurements
      - cell load
      - received power level
      - transmitted power level
      - interference measurements, etc.
  - RRM decision support function
    - CRRM centered decision making
    - Local RRM centered decision making

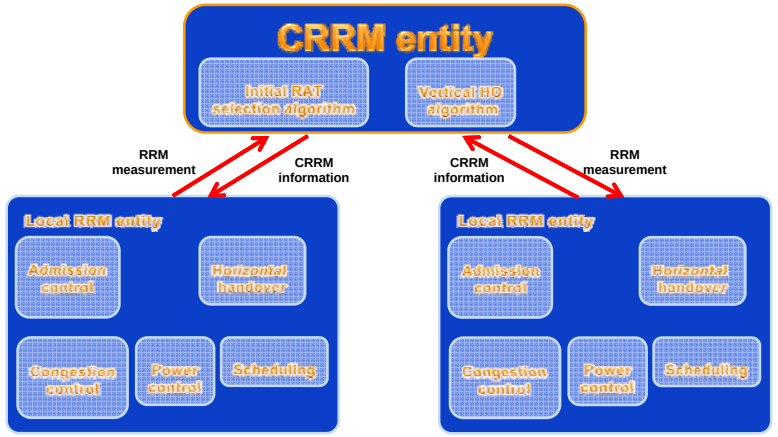
CRRM (Cont'd)

- Function distribution across CRRM and local RRM
  - No CRRM function



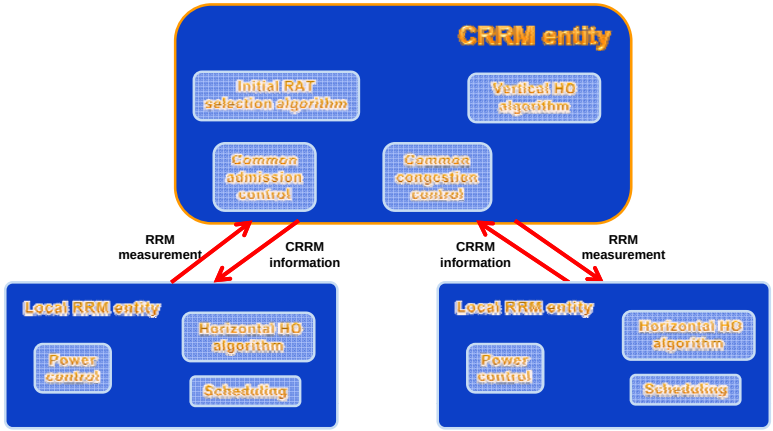
CRRM (Cont'd)

- Function distribution across CRRM and local RRM
  - CRRM functions = Initial RAT selection & Vertical Handover



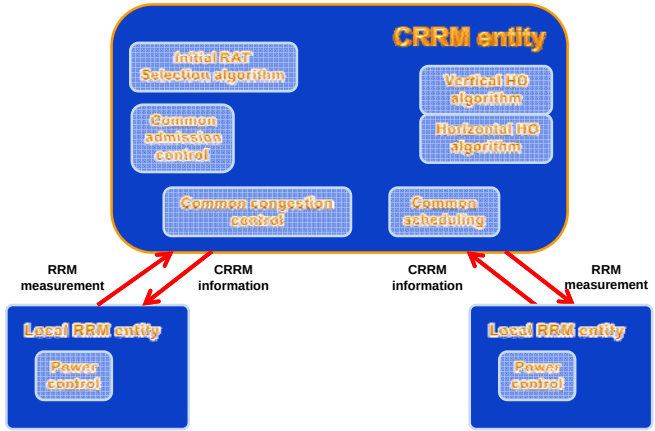
CRRM (Cont'd)

- Function distribution across CRRM and local RRM
  - CRRM functions += Common admission control & congestion control



CRRM (Cont'd)

- Function distribution across CRRM and local RRM
  - CRRM functions += Common packet scheduling & Horizontal handover



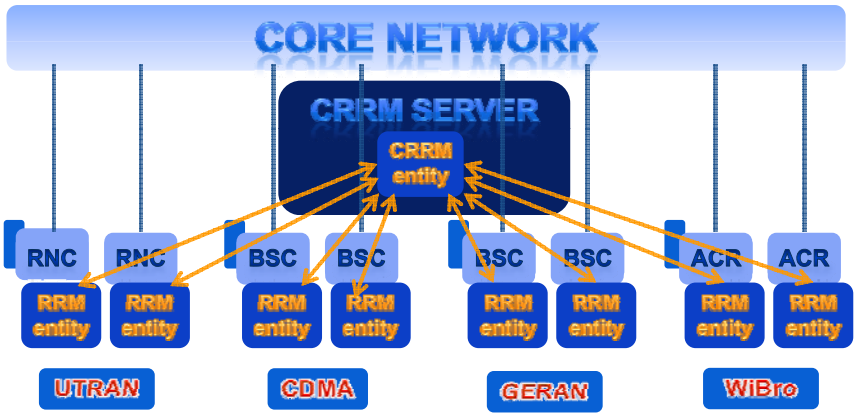
CRRM (Cont'd)

- Interaction degrees between RRM/CRRM entities

Inter-action degree	Inter-action time scale	Functions in CRRM entities	Functions in Local RRM entities
Low	Hours / days	Policy translation and configuration	Initial RAT selection, VHO, Admission control, Congestion control, Horizontal handover, Packet scheduling, Power control
Intermediate	Minutes	Policy translation and configuration, Initial RAT selection, VHO	Admission control, Congestion control, Horizontal handover, Packet scheduling, Power control
High	Seconds	Policy translation and configuration, Initial RAT selection, VHO, Admission control, Congestion control	Packet scheduling, Horizontal handover, Power control
Very high	Milliseconds	Policy translation and configuration, Initial RAT selection, VHO, Admission control, Congestion control, Horizontal handover, Packet scheduling	Power control

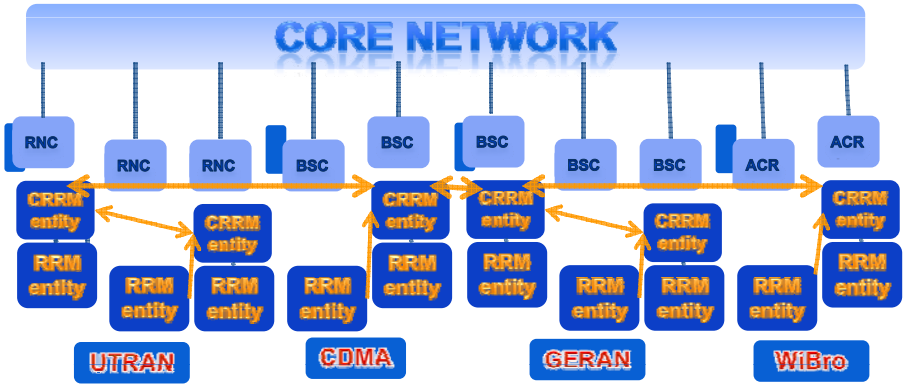
CRRM (Cont'd)

- CRRM Implementation
  - CRRM server approach



CRRM (Cont'd)

- CRRM Implementation (Cont'd)
  - Distributed CRRM approach

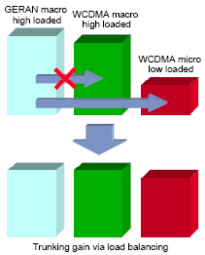


RAT Selection Algorithms

- RAT selection algorithm
  - Initial RAT selection
  - Vertical handover
- Taxonomy
  - Load balancing
  - Service type
  - Network characteristics
  - Economical aspects

RAT Selection Algorithms (Cont'd)

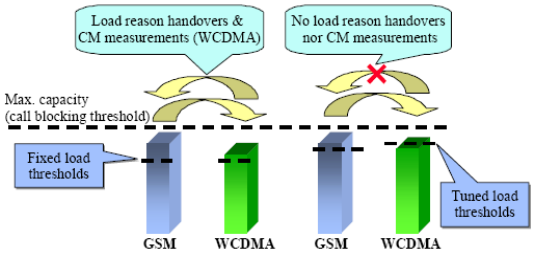
- Taxonomy: Load balancing
  - Performance Evaluation of Common Radio Resource Management, ICC, 2002
    - Predetermined load threshold
    - Directing a real-time user to another system: resulting in less blocking
    - Directing a non-real-time user to another system: resulting in a higher average throughput & smaller average delay



QoS class	Capacity gain with 2 layers	Capacity gain with 4 layers	Capacity gain with 6 layers
Conversational & Streaming	32 kbps: - 144 kbps: - 384 kbps: -	32 kbps: 4% 144 kbps: 11% 384 kbps: 27%	32 kbps: 6% 144 kbps: 16% 384 kbps: 40%
Interactive	Up to 40-100%	Up to 70-140%	Up to 90–180%

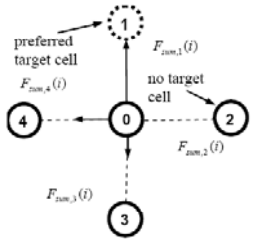
RAT Selection Algorithms (Cont'd)

- Taxonomy: Load balancing
  - Adaptive Load Balancing between Multiple Cell Layers, VTC, 2002
    - Adaptive load threshold rather than fixed one
    - The load threshold of a cell is adjusted periodically according to the loads of its inter-RAT neighboring cells
    - The higher the loads in the neighboring cells, the higher the threshold



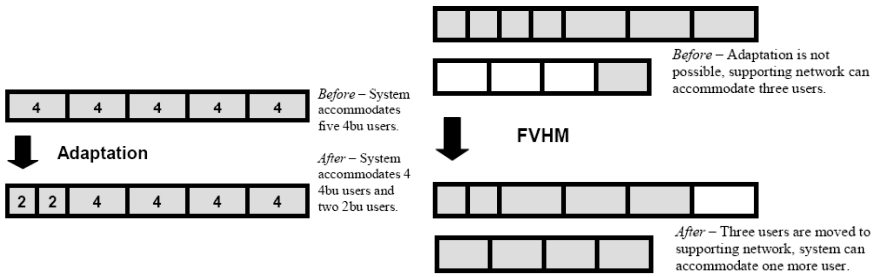
RAT Selection Algorithms (Cont'd)

- Taxonomy: Load balancing
  - Force-based load balancing in co-located UMTS/GSM networks, VTC, 2004
    - The cell with largest force value is selected
    - Force value is the weighted sum of the followings
      - Load force: the free capacity in the target cell
      - QoS force: the difference in the provided QoS between source and target cell
      - Migration attenuation force: the time since the last VHO occurred
      - Handover cost force: the signaling overhead of VHO



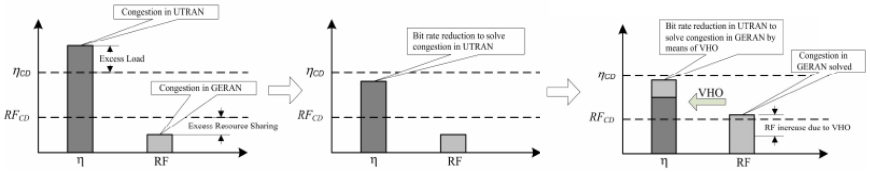
RAT Selection Algorithms (Cont'd)

- Taxonomy: Load balancing
  - Exploiting Vertical Handoffs in Next Generation Radio Resource Management, ICC, 2006
    - Bandwidth Adaptation (BA)
    - Forced Vertical Handoff Module (FVHM)



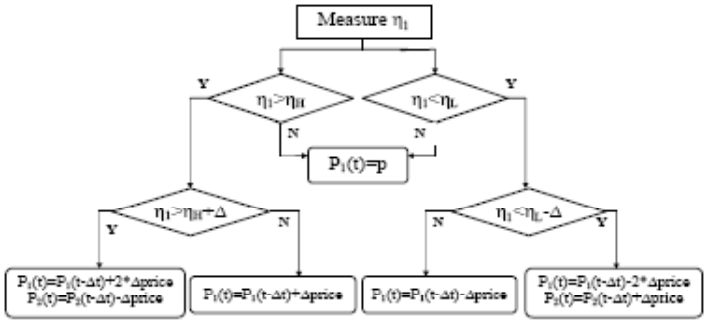
RAT Selection Algorithms (Cont'd)

- Taxonomy: Load balancing + Network characteristics
  - On Managing Multiple Radio Access Congestion Events in B3G Scenarios, VTC, 2007
    - Congestion detection in GERAN: Reduction Factor (RF)
    - Congestion detection in UTRAN: load factor
    - When both networks are in congestion state,
      - Bit Rate Reduction (BRR) in UTRAN
      - Vertical HandOver (VHO) from GERAN to UTRAN



RAT Selection Algorithms (Cont'd)

- Taxonomy: Load balancing + Economical aspects
  - Dynamic Pricing for Decentralised RAT selection in Heterogeneous Scenarios, ISPIMRC, 2006
    - Adjusting the prices of different RATs periodically
    - The price of the high load RAT is increased
    - Users always choose the cheapest RAT

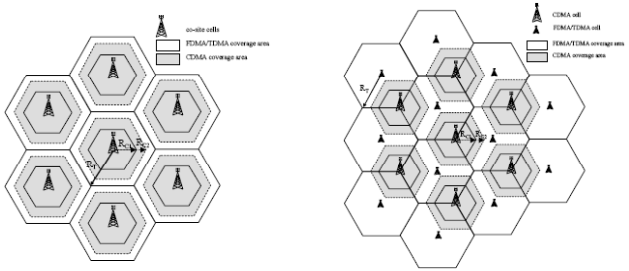


RAT Selection Algorithms (Cont'd)

- Taxonomy: Service type + Network characteristics
  - Policy-based Initial RAT Selection Algorithms in Heterogeneous Networks, MWCN, 2005
    - Service type
      - VG (Voice GERAN) policy
      - VU (Voice UTRAN) policy
      - VG*VU policy
    - Network characteristics
      - IN (indoor GERAN) policy
      - VG*IN policy
      - IN*VG policy
    - Simulation result
      - VG outperforms VU when the cell radius larger than 1km
      - VG*IN outperforms IN*VG when the number of interactive users are much higher than the number of voice users
      - IN*VG outperforms when the number of voice users increases
      - IN*VG achieves much better load balancing than VG*IN

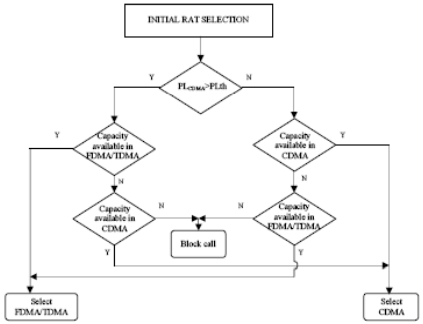
RAT Selection Algorithms (Cont'd)

- Taxonomy: Network characteristics
  - Network-Controlled Cell-Breathing for Capacity Improvement in Heterogeneous CDMA/TDMA Scenarios, WCNC, 2006
    - NCCB
      - Control the effective cell radius of the CDMA-based system
      - The interference level of the CDMA-based RAT is reduced
      - The target coverage area is assured by means of the cooperation of FDMA/TDMA-based RATs

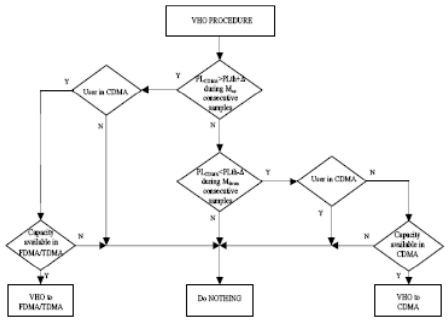


RAT Selection Algorithms (Cont'd)

- Taxonomy: Network characteristics
  - Network-Controlled Cell-Breathing for Capacity Improvement in Heterogeneous CDMA/TDMA Scenarios, WCNC, 2006 (Cont'd)



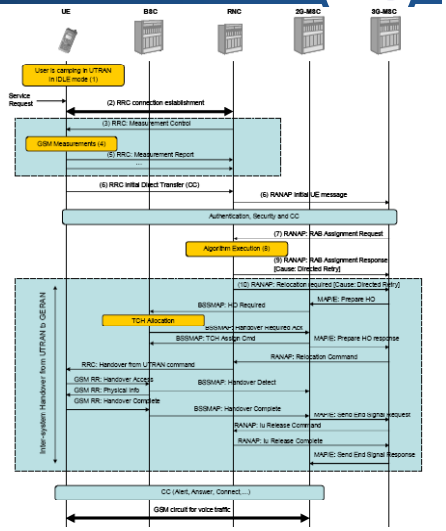
RATS Algorithm



VHO Algorithm

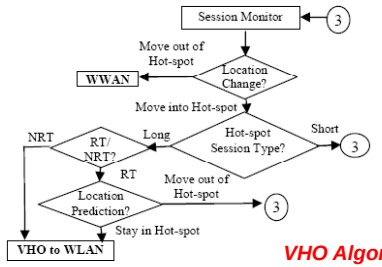
RAT Selection Algorithms (Cont'd)

- Taxonomy: Network characteristics
  - RAT Selection in 3GPP-based Cellular Heterogeneous Networks: from Theory to Practical Implementation, WCNC, 2007
    - Analysis model of the scheme in the previous slide
    - Practical implementation on real systems

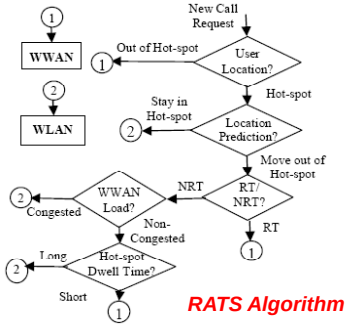


RAT Selection Algorithms (Cont'd)

- Taxonomy: Network characteristics
  - Performance Analysis of Common Radio Resource Management Scheme in Multi-service Heterogeneous Wireless Networks, WCNC, 2007
    - "Always WWAN" scheme
    - "WLAN if coverage" scheme
    - Adaptive algorithm



VHO Algorithm



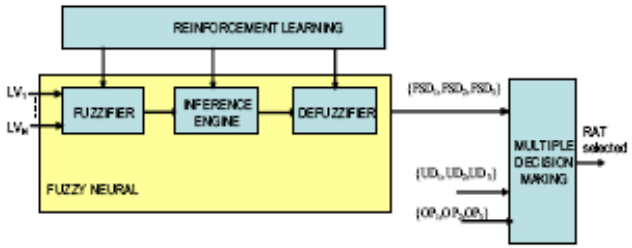
RATS Algorithm

RAT Selection Algorithms (Cont'd)

- Taxonomy: Network characteristics
  - Performance Analysis of Common Radio Resource Management Scheme in Multi-service Heterogeneous Wireless Networks, WCNC, 2007 (Cont'd)
    - Simulation result
      - Adaptive algorithm outperforms the other two in terms of call blocking probabililty
      - "Always WWAN" scheme outperforms "WLAN if coverage" when most of the users are outdoor
      - "WLAN if coverage" scheme outperforms "Always WWAN" when most of the users are indoor

RAT Selection Algorithms (Cont'd)

- Taxonomy: Economical aspects
  - A Novel Joint Radio Resource Management Approach with Reinforcement Learning Mechanism, IPCCC, 2005
    - Consider both technical and economical aspects
    - Three main blocks
      - Fuzzy neural algorithm: Fuzzy Selected Decision, 0 ≤ FSD ≤ 1
      - Reinforcement Learning
      - Multiple decision-making

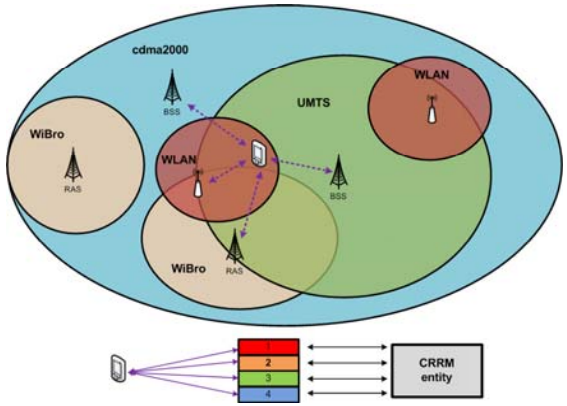


Preliminary Study on CRRM

- Integrated RAT selection
  - When a new user comes to a network, CRRM chooses target network by objective function
- Integrated vertical handover
  - If a network has not efficient capacity for incoming new user
  - CRRM chooses candidate target nodes and networks according to objective function

Preliminary Study on CRRM (Cont'd)

- Integrated RAT selection



Preliminary Study on CRRM (Cont'd)

- Integrated RAT selection algorithm

$Input: b_{req}, \delta_k, B_{rem,k} (1 \le k \le K)$

$Ouput: \mathrm{A} = (a_1, a_2, \cdots, a_K)$

$\Theta = \{k \mid 1 \le k \le K\}, a_k = 0 (1 \le k \le K)$

while $\Theta \neq 0$ *and* $b_{req} > 0$ *do*

$j = k_{\max} \leftarrow \max\{ f_1(k) \mid \forall k \in \Theta \}$

if $b_{req} \le B_{rem,j}$ *then* $a_j = b_{req}$

else $a_j = B_{rem,j}$ *endif*

$B_{rem,j} = B_{rem,j} - a_j$

$b_{req} = b_{req} - a_j$

$\Theta = \Theta - \{j\}$

end while

$$f_1(k) = \left(\frac{B_{rem,k} \times \delta_k}{B_{\max}} \times \alpha\right) + \left(1 - \frac{C_k}{C_{\max}}\right)(1-\alpha)$$

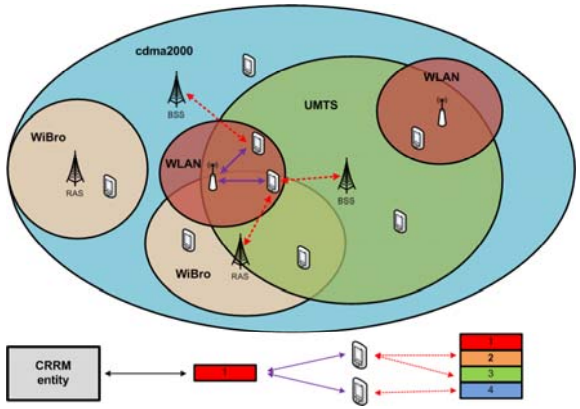
Symbol	Definition
b_{req}	Bandwidth requested
δ_k	Signal strength at network *k*
$B_{rem,k}$	Remaining bandwidth of network *k*
K	Number of networks
A	Allocation vector

Preliminary Study on CRRM (Cont'd)

- Objective function for integrated RAT selection algorithm
  - RAT cost
    - RAT which has lower cost can have larger value
  - RAT signal strength
    - RAT which has higher signal strength can have larger value
  - RAT bandwidth
    - RAT which has larger available bandwidth can have larger value

Preliminary Study on CRRM (Cont'd)

- Integrated vertical handover



Preliminary Study on CRRM (Cont'd)

- Integrated vertical handover algorithm

$Input: b_{req}, \mathrm{A} = \|a_{i,k}\| (1 \le i \le N, 1 \le k \le K)$

$Ouput: \mathrm{H}_{\min}$

$b_{req} = b_{req} * \gamma$

$Search \quad \Omega = \{\mathrm{H} \mid \mathrm{H} = \|h_{i,k}\|, 1 \le i \le N, 1 \le k \le K\}$

$such \ that \ b_{req} \le \sum_{i=1}^{N} \sum_{k=1}^{K-1} h_{i,k} \times a_{i,k}$

$where \ h_{i,k} = 1 \ if \ handover$

$h_{i,k} = 0 \ otherwise$

$\mathrm{H}_{\min} \leftarrow \min\{ f_2(\mathrm{H}) \mid \forall \mathrm{H} \in \Omega \}$

Symbol	Definition
N	Number of users
$\delta_{i,k}$	Signal strength of user *i* at network *k*
A	Allocation matrix
H	Handover execution matrix

$$f_2(\mathrm{H}) = \frac{1}{N} \sum_{i=1}^{N} \frac{1}{K} \sum_{k=1}^{K-1} \{ (\frac{b_{rem,k} \times \delta_{i,k}}{B_{\max}} \times \beta) + c(1 - \frac{C_k \times c}{C_{\max}})(1 - \beta) \}$$

$$b_{rem,k} = \begin{cases} B_{rem,k} & if \ h_{i,k} \ne 0 \\ 0 & if \ h_{i,k} = 0 \end{cases}$$

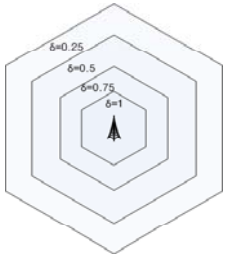
$$c = \begin{cases} 1 \ if \ h_{i,k} \ne 0 \\ 0 \ if \ h_{i,k} = 0 \end{cases}$$

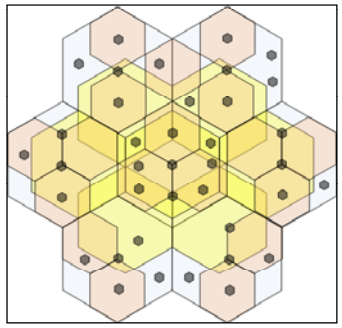
Preliminary Study on CRRM (Cont'd)

- Objective function for integrated vertical handover algorithm
  - RAT network cost
    - The network which has lower cost can have larger value
  - RAT signal strength
    - The network which has higher signal strength can have larger value
  - Select minimum number of vertical handovers

Preliminary Study on CRRM (Cont'd)

- Simulation model
  - Network coverage & bandwidth
    - CDMA2000: 2km, 2Mbps
    - UMTS: 1.7km, 3Mbps
    - WiBro: 1km, 5Mbps
    - WLAN: 0.1km, 10Mbps
  - Signal strength





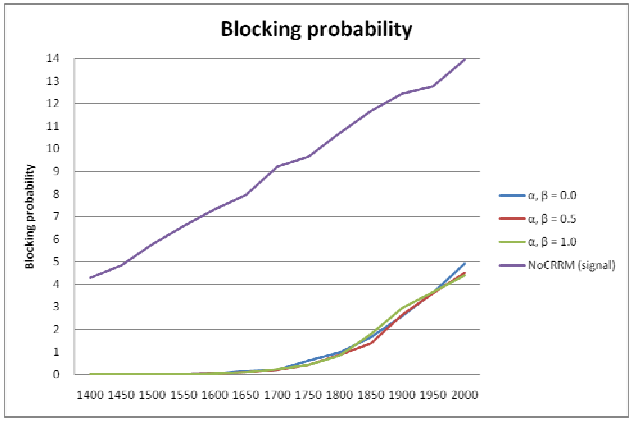
Simulated network coverage

Preliminary Study on CRRM (Cont'd)

- Simulation evaluation model (Cont'd)
  - Service characteristics
    - VoIP (25%)
      - Data rate : 12.2kbps
      - Service time : 60s (expntl)
      - Interarrival Time : 300s (expntl)
    - VOD (25%)
      - Data rate : 64kbps
      - Service time : 60s (expntl)
      - Inter arrival time : 300s (expntl)
    - WEB (25%)
      - Data rate : 128kbps
      - Service time : 5s (expntl)
      - Inter arrival time : 10s (expntl)
    - FTP (25%)
      - Data rate : 256kbps
      - Service time : 10s (expntl)
      - Inter arrival time : 50s (expntl)

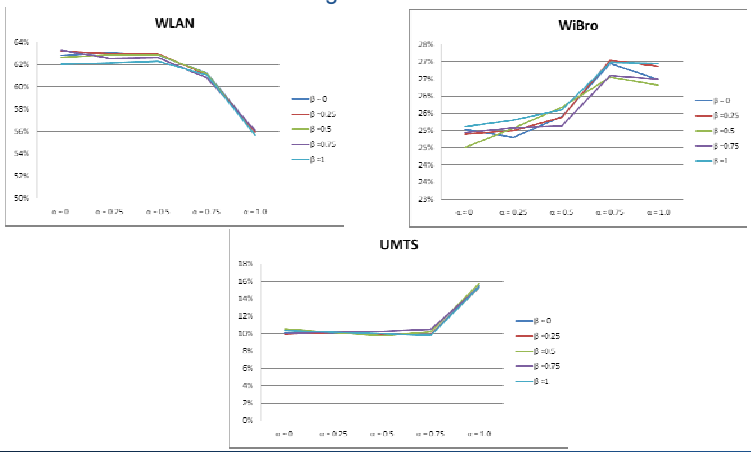
Preliminary Study on CRRM (Cont'd)

- Simulation result
  - Blocking probability according to the number of users



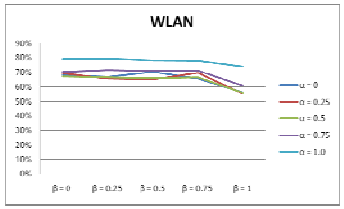
Preliminary Study on CRRM (Cont'd)

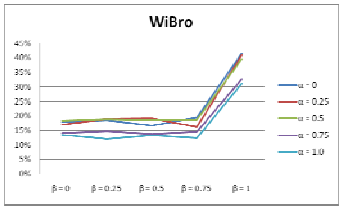
- Simulation result (Cont'd)
  - Network utilization according to α

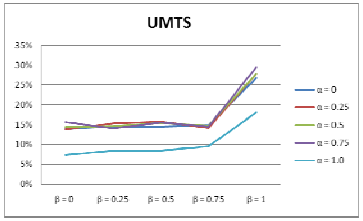


Preliminary Study on CRRM (Cont'd)

- Simulation result (Cont'd)
  - Network utilization according to β







Summary & Future Work

- Summary
  - Introduction to CRRM/JRRM concept
  - Survey on RAT selection algorithms
  - Preliminary study on CRRM
- Future work
  - Common admission control
  - Common congestion control
  - Common packet scheduling

MESL

Thank You !