國立臺北大學
資訊工程學系
Department of Computer Science and Information Engineering,

Chapter 8:
Relay-Assisted Protocol of Spectrum Mobility and Handover in Cognitive LTE Network

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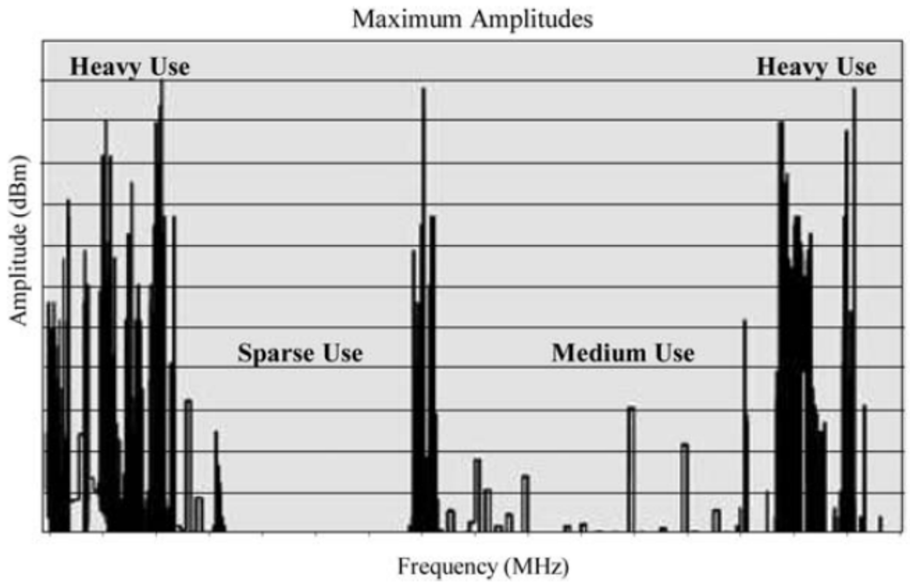
Outline

- Introduction
- Related works
- Motivation and basic ideas
- A relay-assisted protocol of spectrum mobility and handover
- Simulation results
- Conclusions

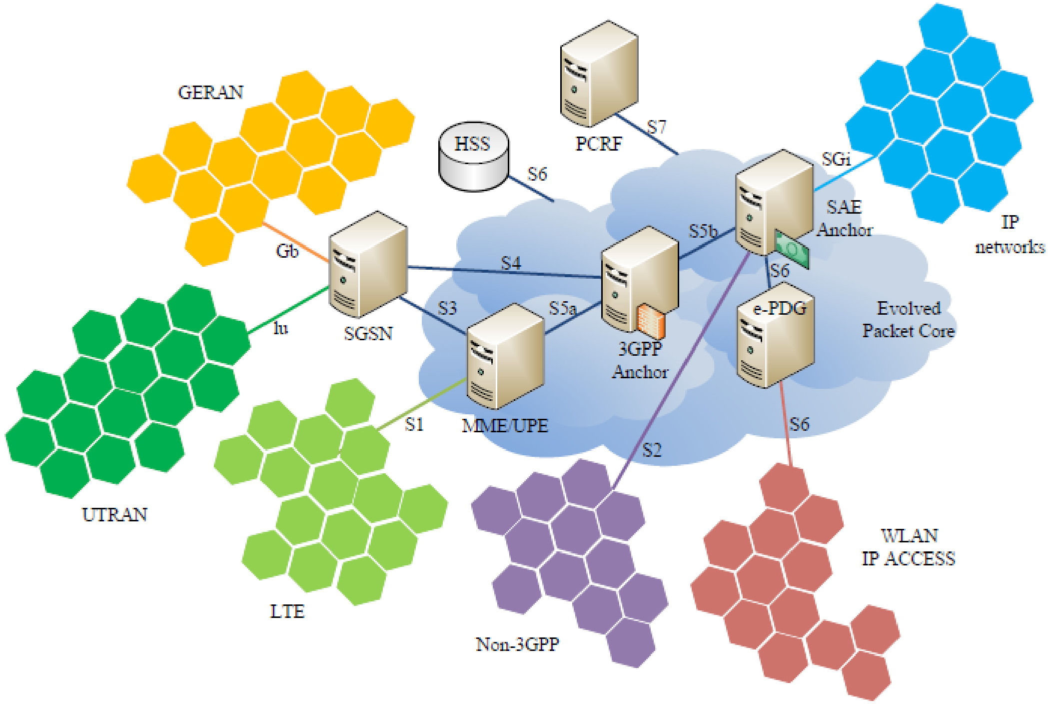
Introduction

- Cognitive radio
  - Military network
  - Integration of leased wireless networks
  - Spectrum utilization
    - According to Federal Communications Commission (FCC) , temporal and geographical variations in the utilization of the assigned spectrum range from 15% to 85%

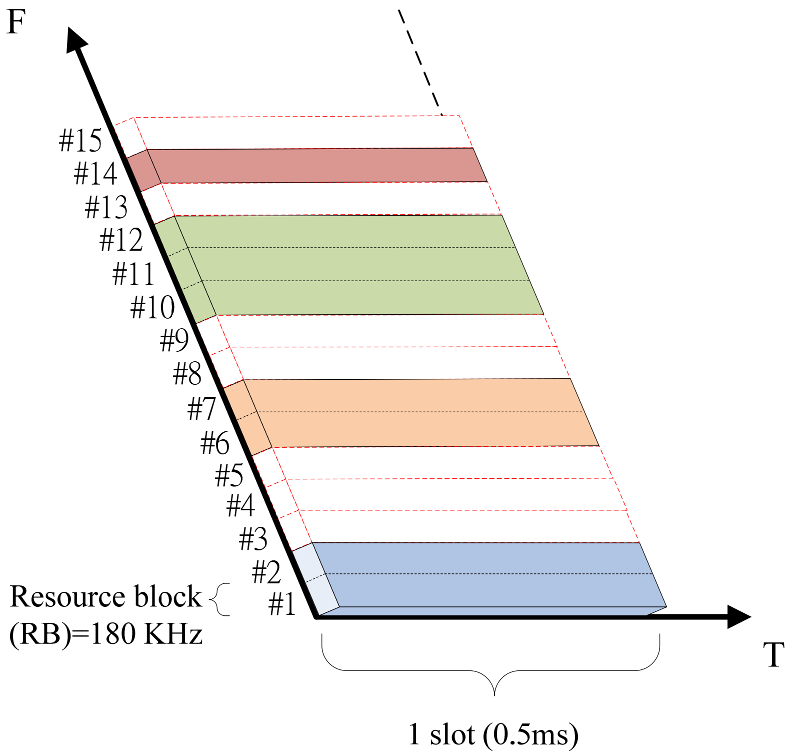


References: FCC. "ET Docket No 03-237 Notice of inquiry and notice of proposed Rulemaking". November 2003.

LTE systems



(a) LTE systems core architecture

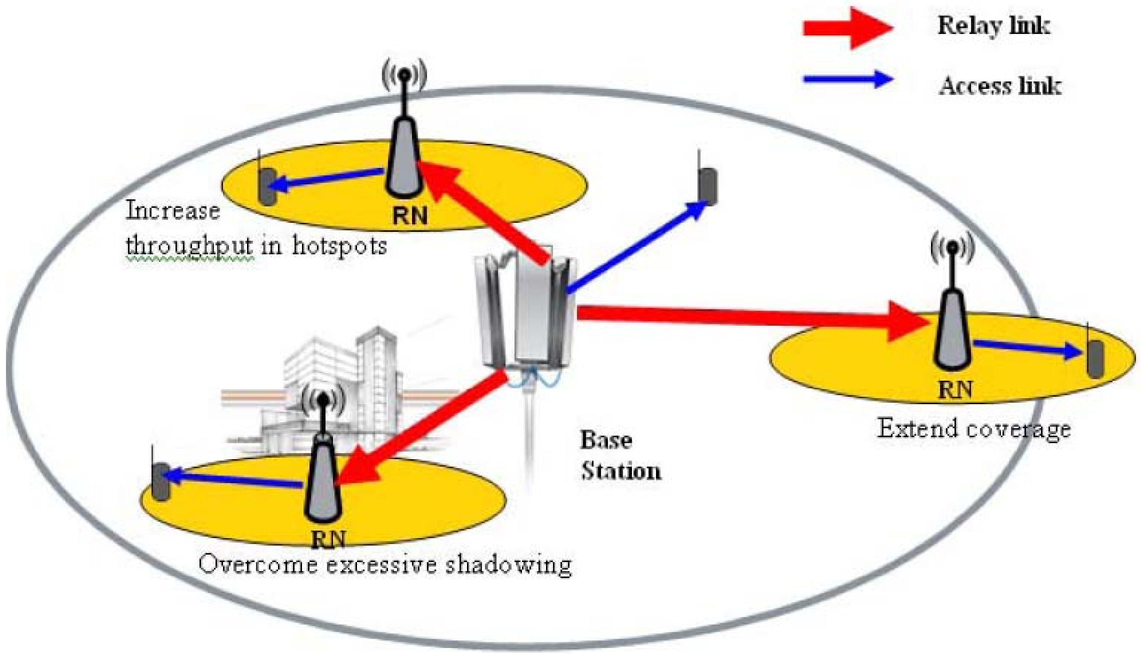


(b) LTE systems spectrum architecture

References: 3rd Generation Partnership Project TS36.300 , *"Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Overall description, Release 8, v8.8.0*

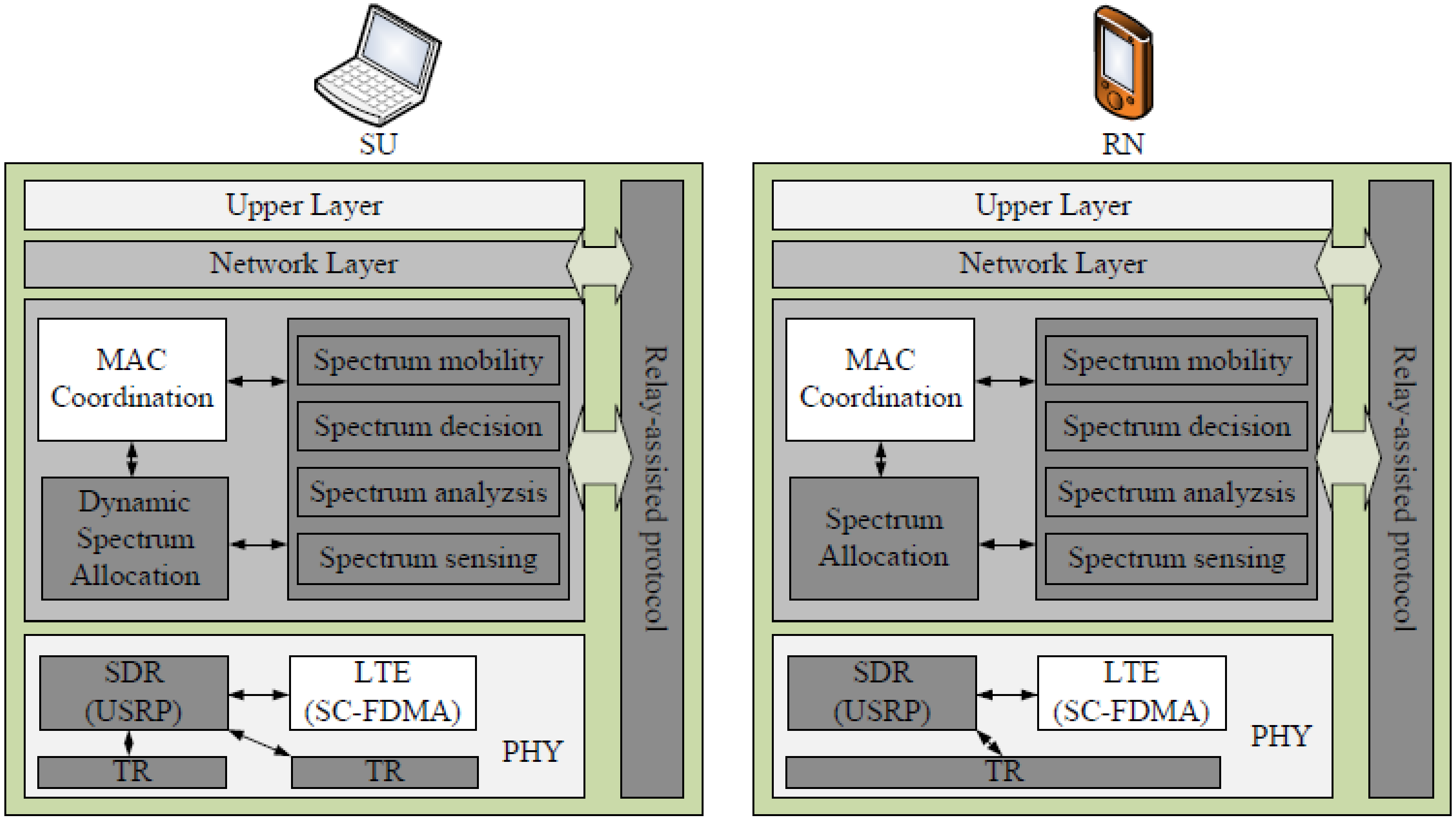
Introduction (cont.)

- Relay
  - Improve performance without extra bandwidth
  - Static relay
  - Dynamic relay (mobile user act as relay node)



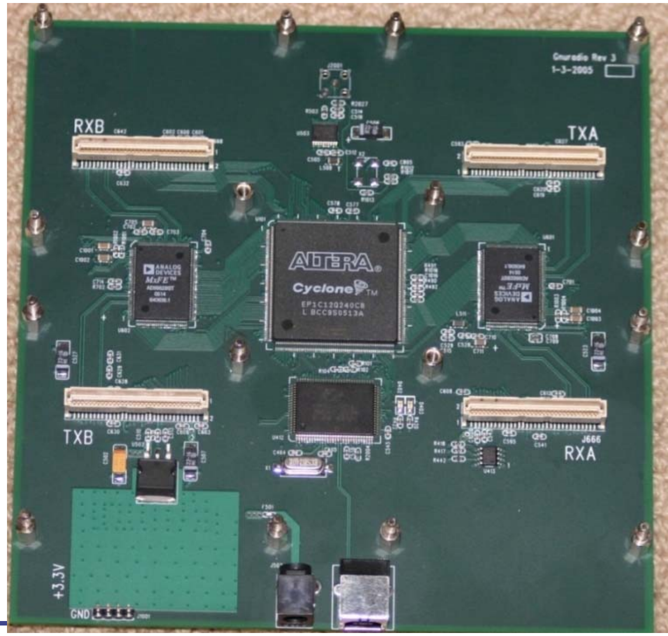
References: Teyeb *et al*. "Handover Framework for Relay Enhanced LTE Networks". 2009.

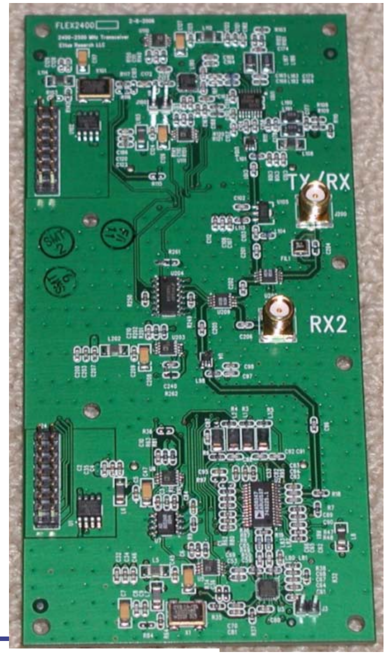
Cognitive user (SU and RN) architecture



Software defined radio (SDR)

- SDR components
  - USRP+RFX2400
  - GNU radio
- SDR applications
  - Access different network by reconfigurable technique
  - Spectrum sensing
  - Spectrum analysis
  - Spectrum decision
  - Spectrum mobility





References: "USRP & RFX2400", *http://www.ettus.com*
"GNU radio", *http://gnuradio.org*

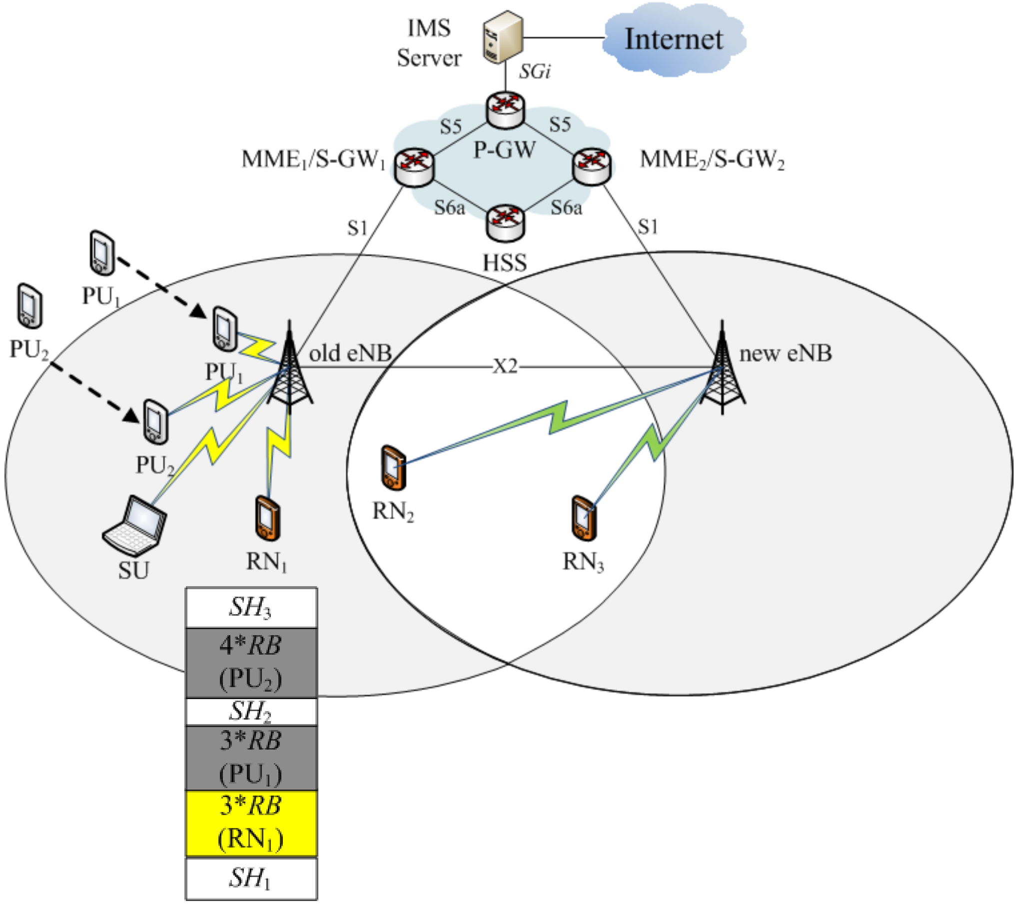
Implement environment

- IMS server

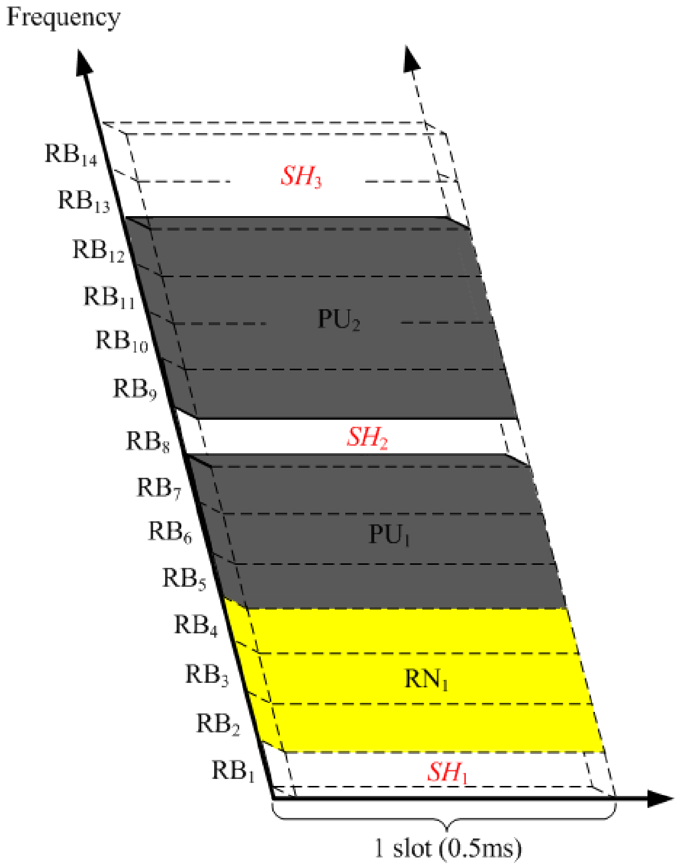
- MN, HA, and AR

References: “USRP & RFX2400“, *http://www.ettus.com*
“GNU radio”, *http://gnuradio.org*

Spectrum sensing and spectrum distribution



(a)



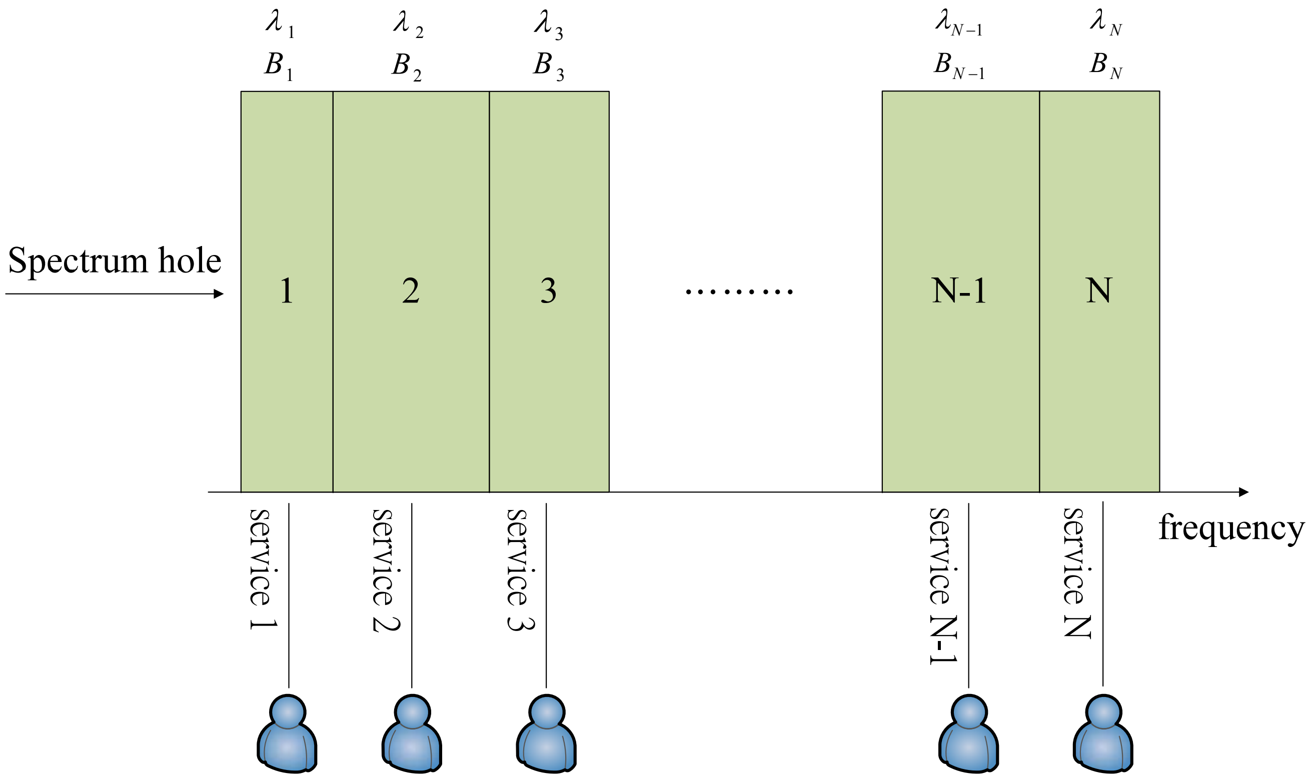
(b)

Related works

- There are some literatures for layer 2 and relay-assisted channel selection in cognitive radio.
  - Jo *et al.*, "Efficient Spectrum Matching Based on Spectrum Characteristics in Cognitive" *IEEE Wireless Telecommunications Symposium* (**WTS 2008**)
    - According the service required time select a spectrum hole.
  - Jia *et al.*, "Cooperative Relay for Cognitive Radio Networks" *IEEE International Conference on Computer Communications* (**INFOCOM 2009**)
    - According history information to predict the spectrum hole idle time and selection.

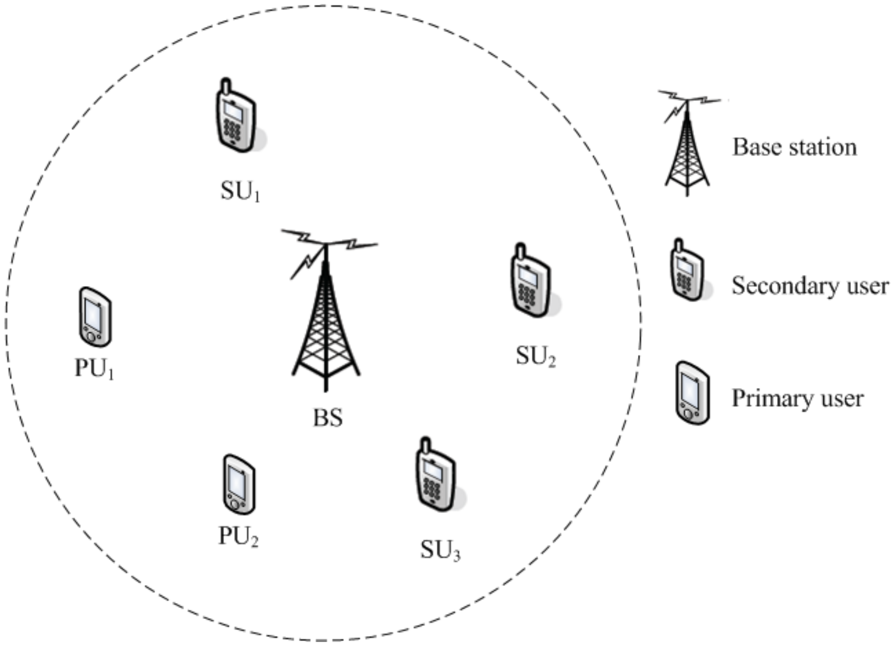
Jo *et al.*, "Efficient Spectrum Matching Based on Spectrum Characteristics in Cognitive" *IEEE Wireless Telecommunications Symposium* (**WTS 2008**)

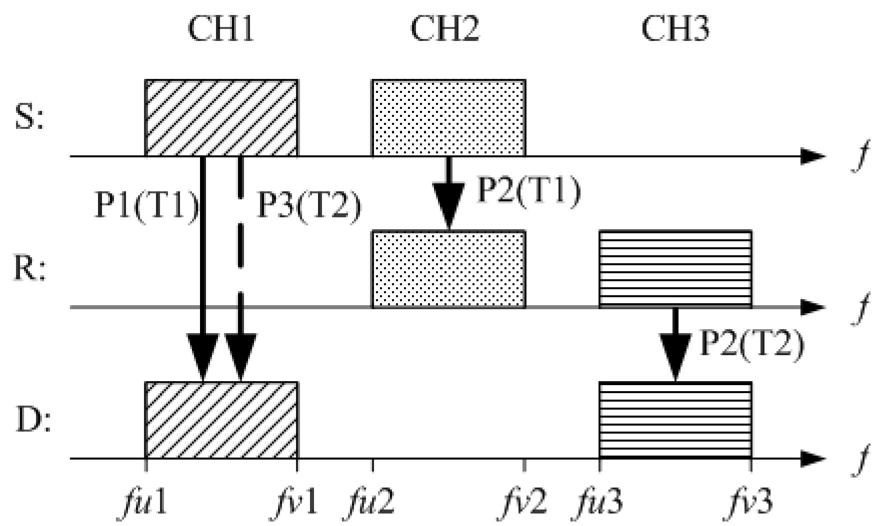
- λ denotes the spectrum hole holding time.
- B denotes the spectrum hole bandwidth.
- Every user has service data, respectively.



Jia *et al.*, "Cooperative Relay for Cognitive Radio Networks" *IEEE International Conference of Computer Communications* (**INFOCOM 2009**)

- S denotes the source node and R denotes the relay node.
- T1 denotes the time slot 1 and P1 denotes the packet 1.
- Every source node uses a relay node to transmit data.

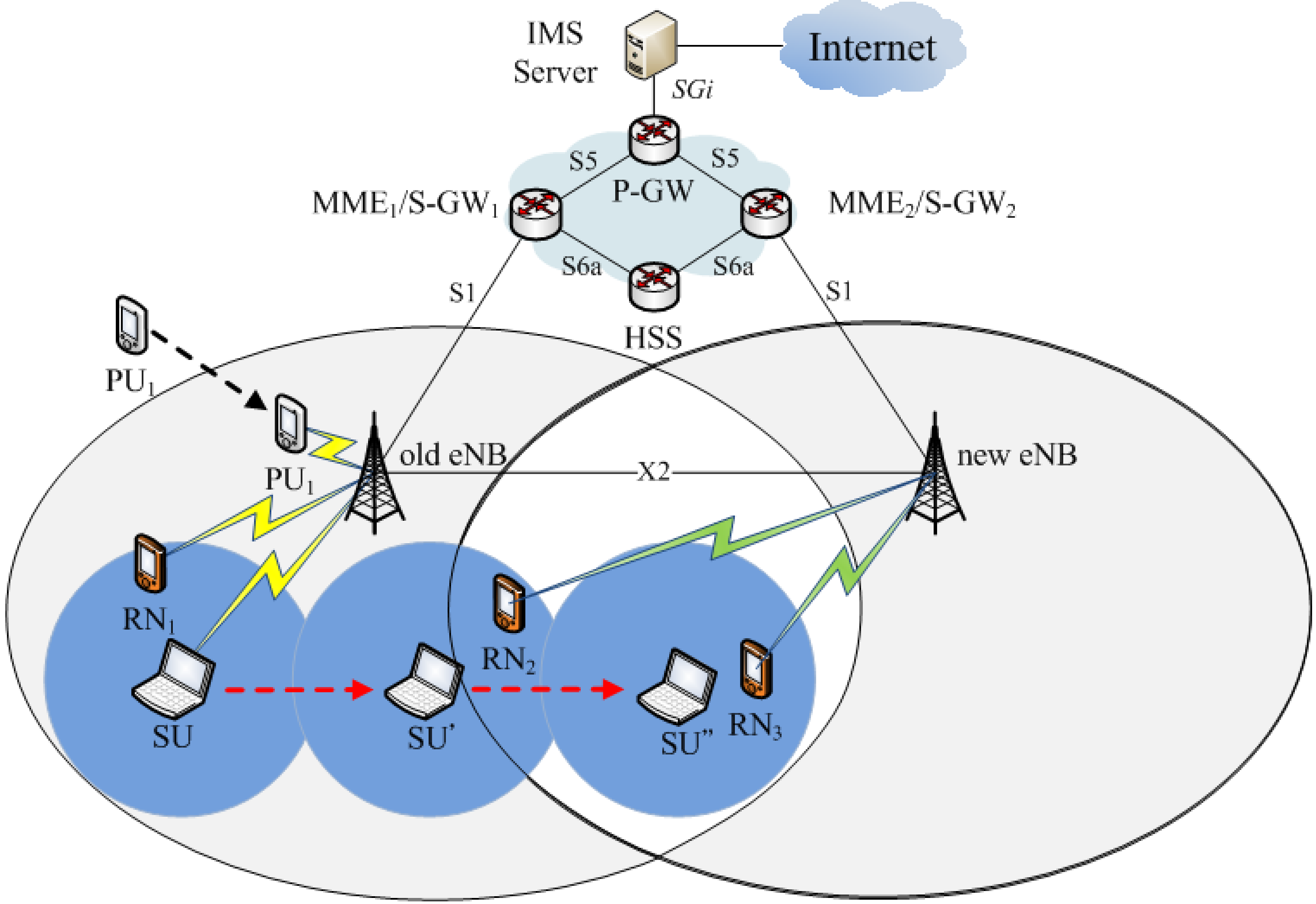




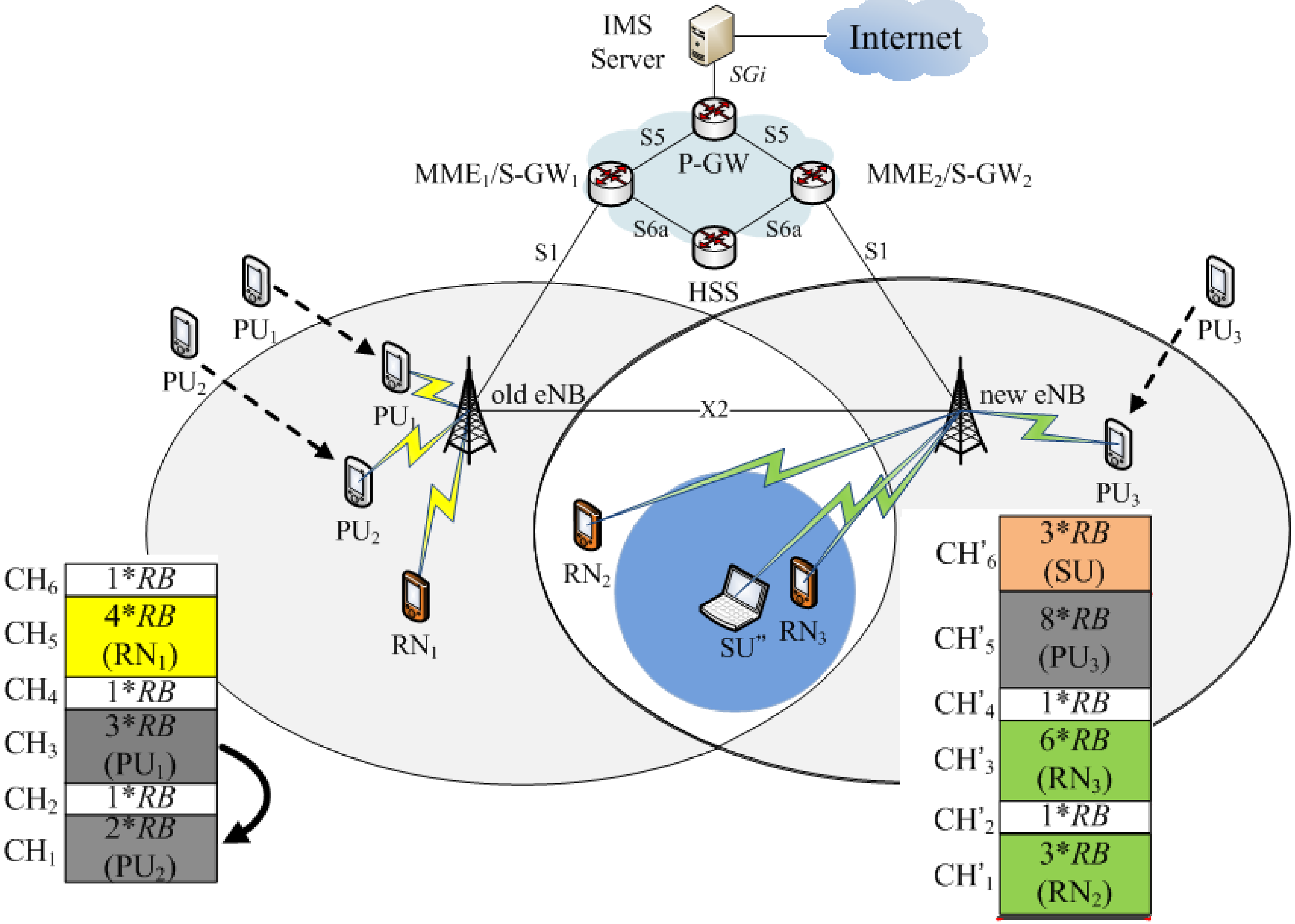
Motivation and basic ideas

- Most literatures are not consider layer 3 handover issue.
- In the flexible bandwidth condition, the transmission rate of every spectrum holes is different, the maximum idle time spectrum hole selection scheme may decrease the successful transmission rate and increase the transmission time.
- Improve performance through relay-assisted.
- According to located area, the proposed scheme evaluates the expected transmission time of all spectrum holes (free and RN) with the channel characters and user condition to achieve the layer 2 spectrum mobility and layer 3 handover.

System model

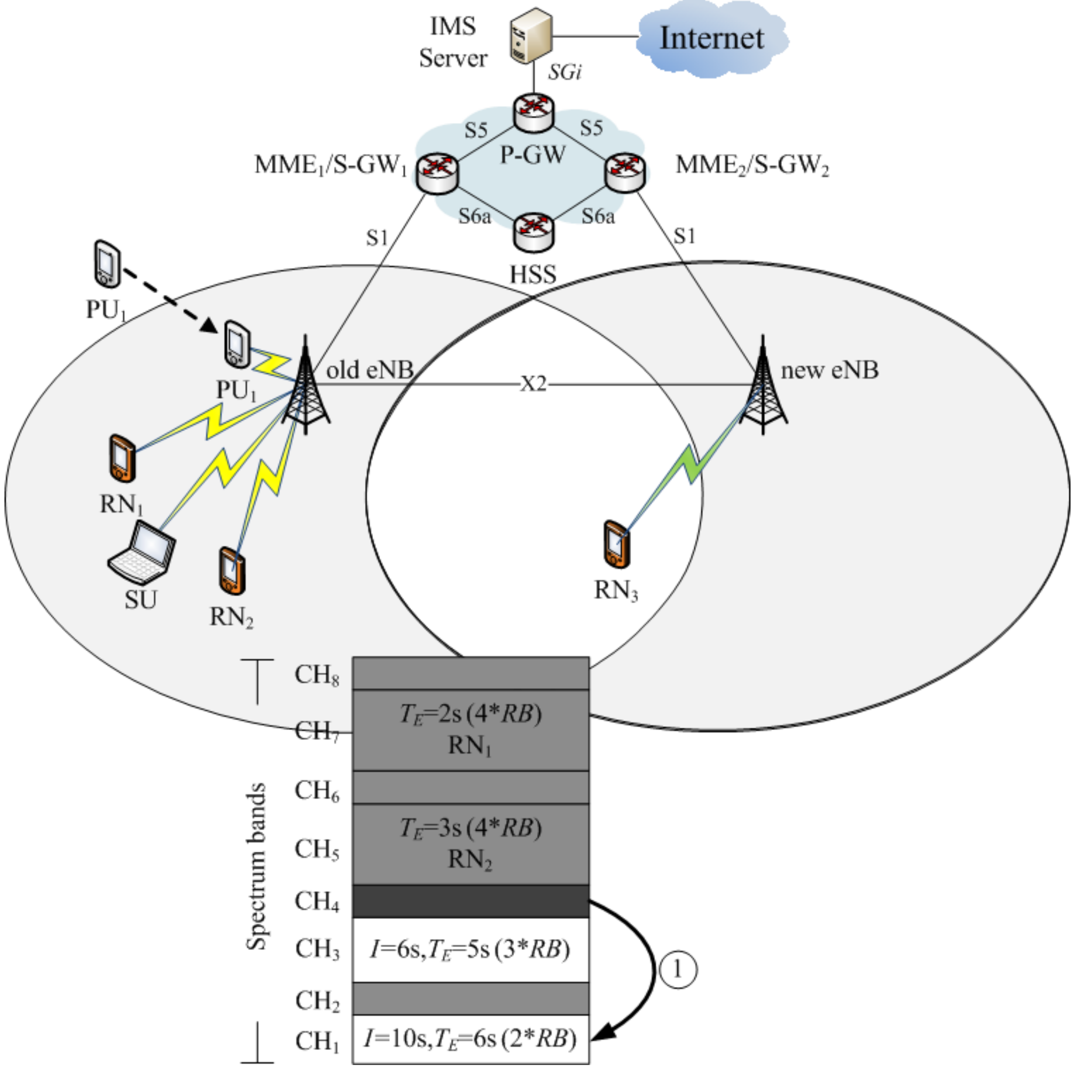


Overview



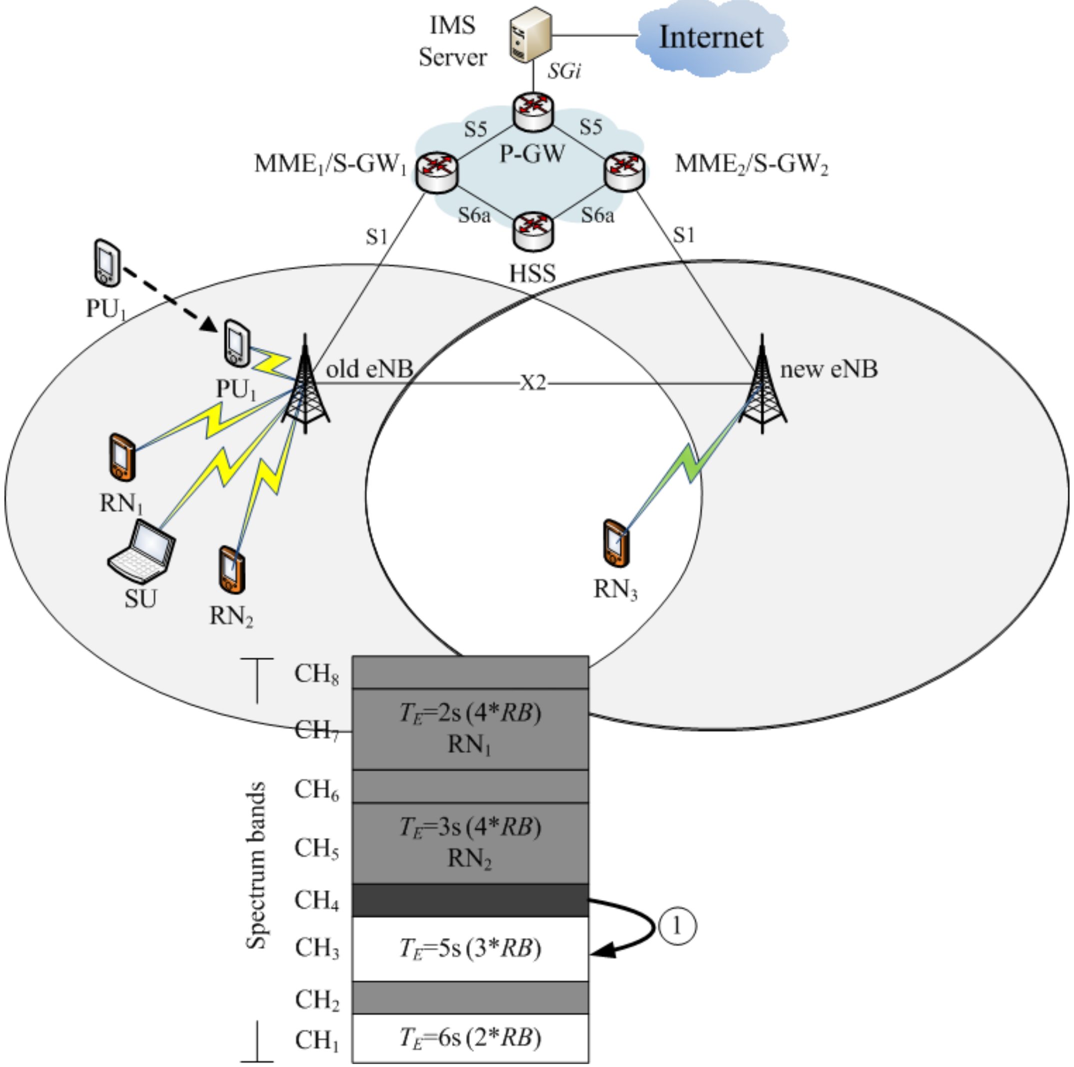
IMS
Server
Internet
SGi
S5
S5
P-GW
MME1/S-GW1
MME2/S-GW2
S6a
S6a
S1
S1
HSS
PU1
PU2
PU1
old eNB
X2
new eNB
PU3
PU3
PU2
RN1
RN2
SU"
RN3
CH6 1*RB
CH5 4*RB (RN1)
CH4 1*RB
CH3 3*RB (PU1)
CH2 1*RB
CH1 2*RB (PU2)
CH'6 3*RB (SU)
CH'5 8*RB (PU3)
CH'4 1*RB
CH'3 6*RB (RN3)
CH'2 1*RB
CH'1 3*RB (RN2)

Protocol Comparison – max idle time



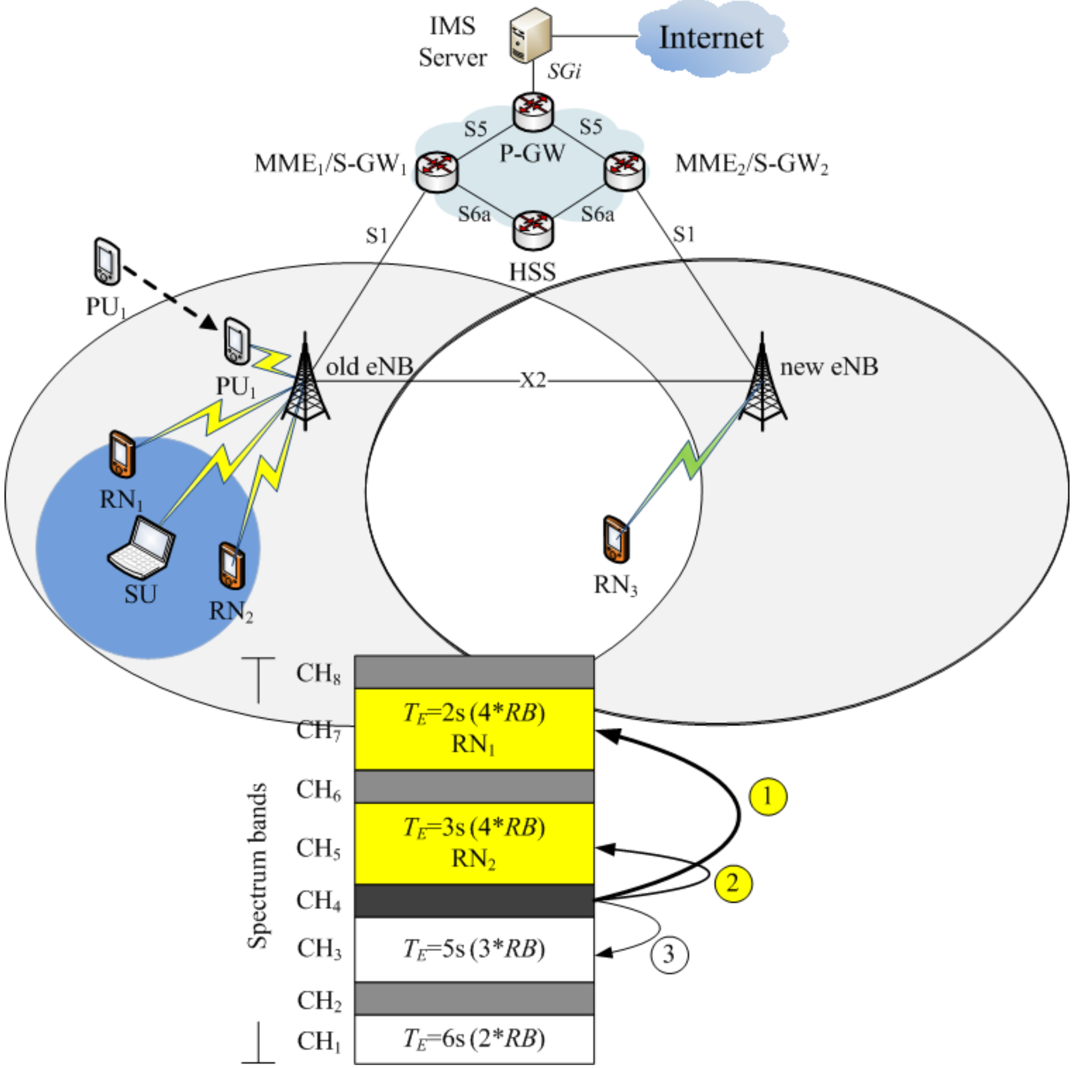
(a) Select channel with the maximum idle time

Protocol Comparison – min expected transmission time



(b) Select channel with the minimum expected transmission time

Protocol Comparison – proposed scheme



(c) Select channel with our proposed scheme

Contribution

- Layer 3 handover with the adaptive spectrum resources and before the signal strength down to the threshold.
- Layer 2 spectrum mobility with the characters of spectrum holes to avoid frequently spectrum mobility.
- The relay-assisted minimum expected transmission time predicts the spectrum holes usage and availability is efficient than the selection scheme with the maximum idle time.
- Improve performance through relay-assisted which with rich resource.

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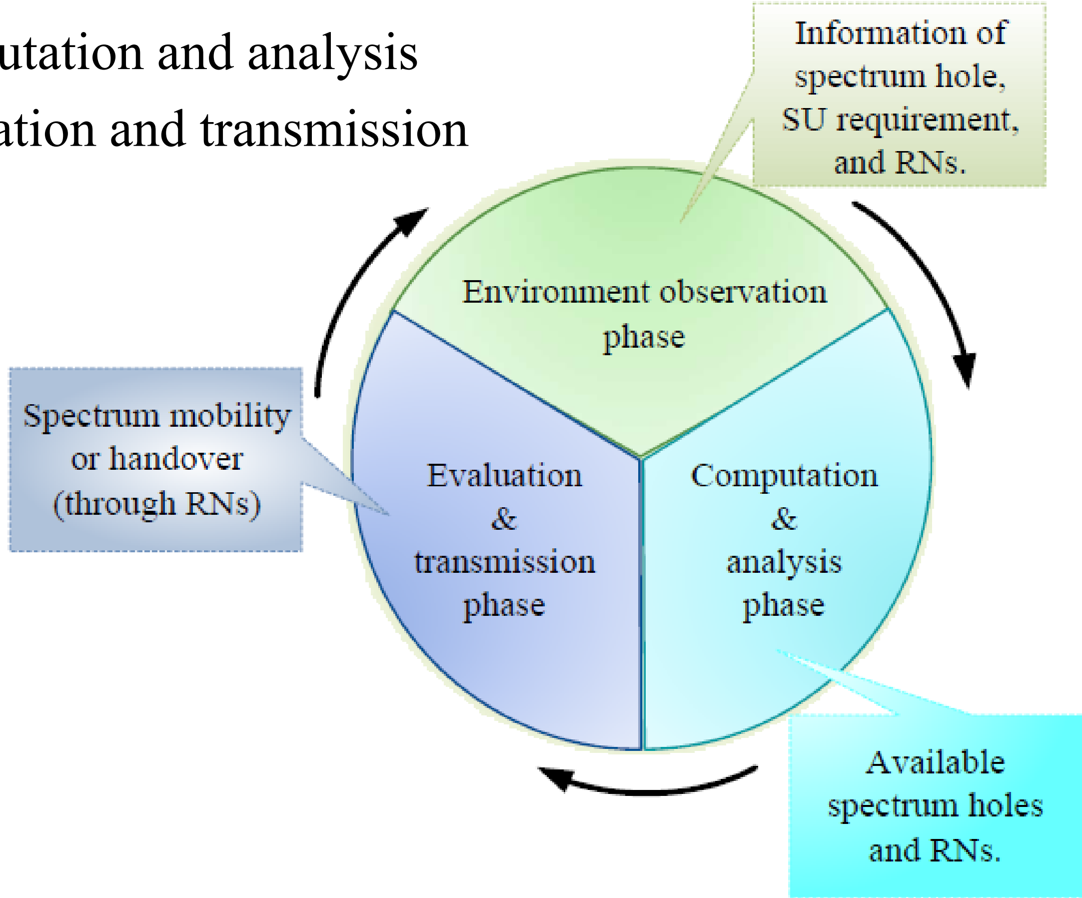
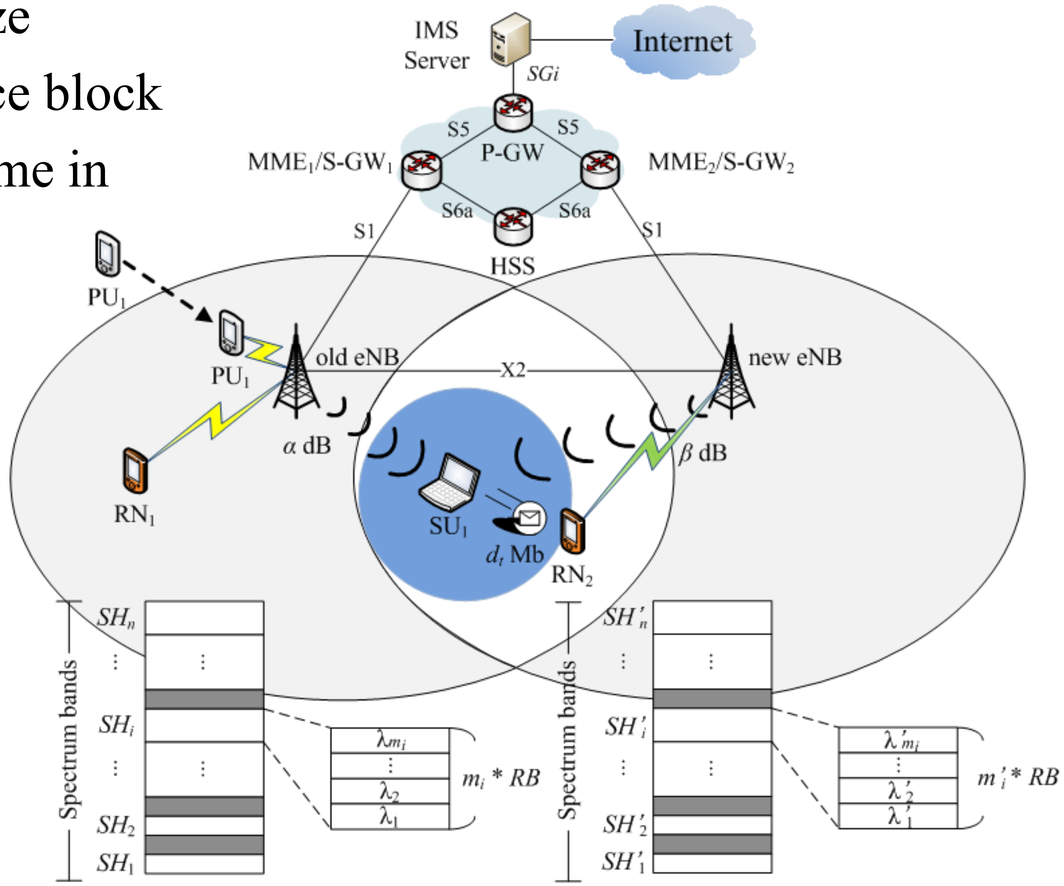
A relay-assisted protocol of spectrum mobility and handover in LTE systems

- There are three operation phases
  - Environment observation
  - Computation and analysis
  - Evaluation and transmission



Environment observation

- Observed information
  - α, β : received signal strength (dB)
  - d_t: current service data size
  - λm_i: the number of resource block be occupied in unit time in spectrum hole i.



Computation and analysis (cont.)

- In this phase, the transmission rate, required time of data transmission, and the probability of spectrum hole unoccupied is analyzed.
- Some communication formula is needed.
  - Signal strength to SNR

$$dB = 10 \log SNR$$

  - Shannon theorem

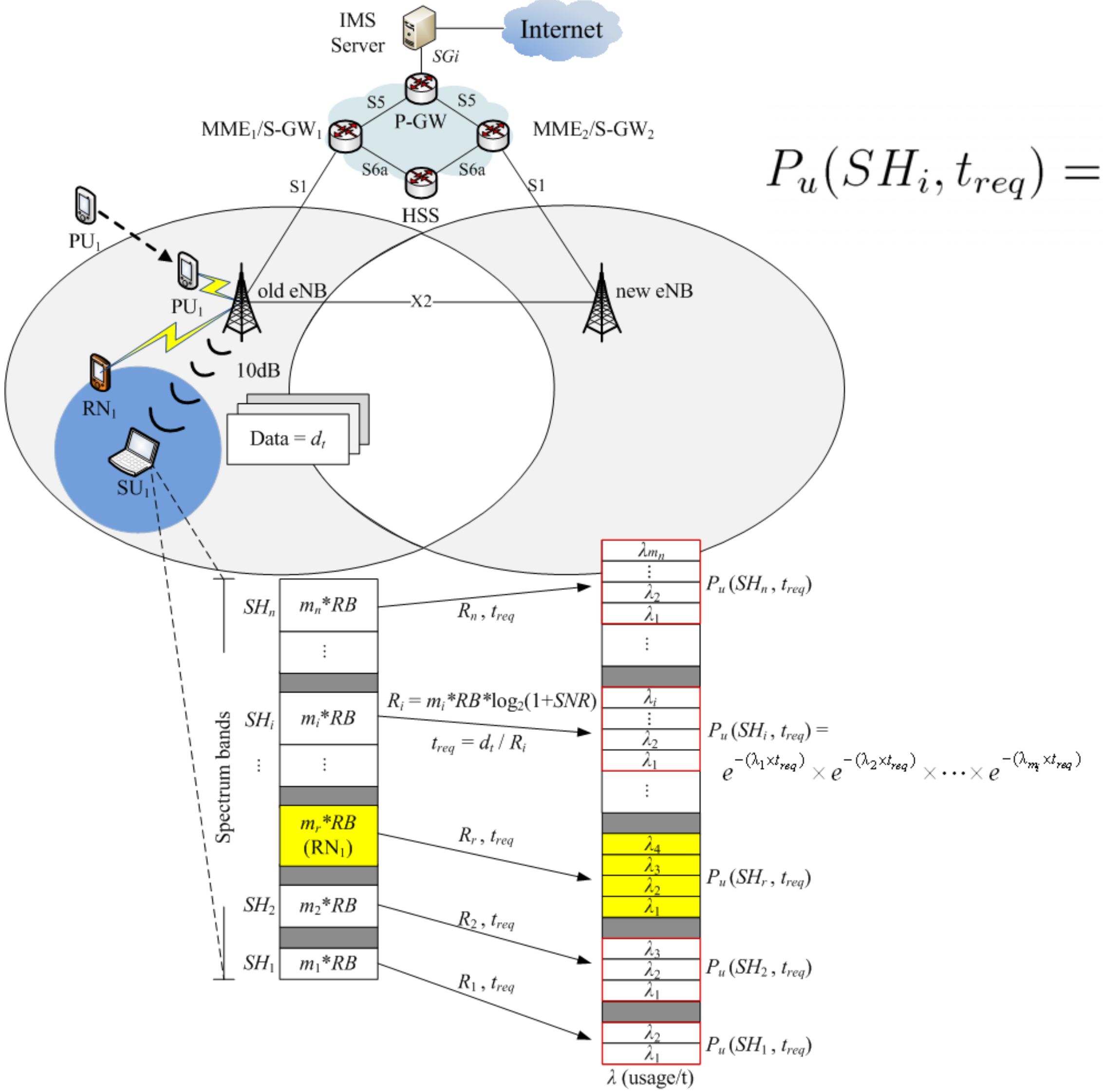
$$C = B \times \log_2(1 + SNR)$$

  - Poisson distribution

$$P(k,T) = \frac{(\lambda T)^k}{k!} e^{-\lambda T}$$

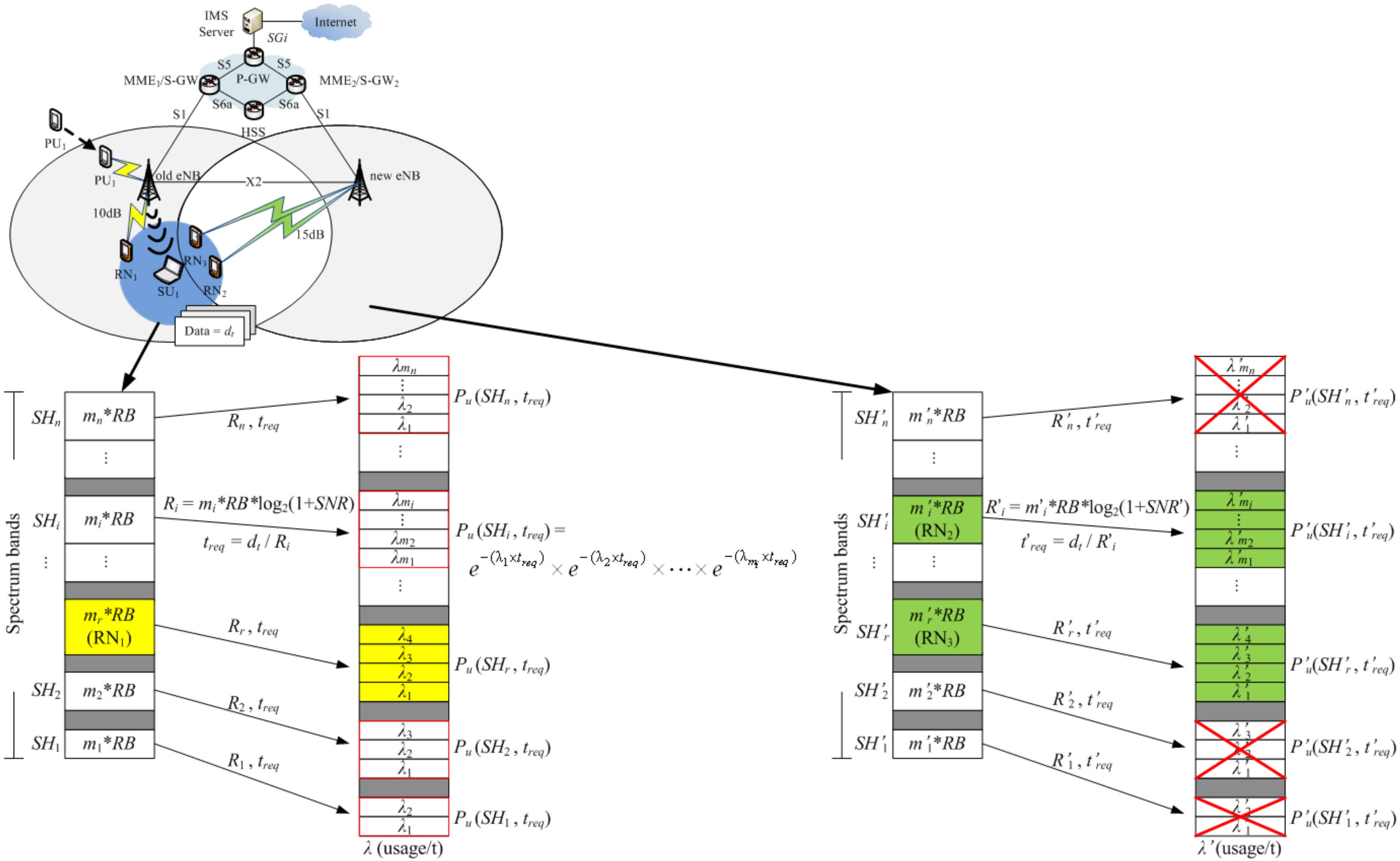
Reference: CE Shannon. "A mathematical theory of communication". *ACM SIGMOBILE Mobile Computing and Communications Review*, 5(1):3–55, 2001. L. Bortkiewicz " Das Gesetz der kleinen Zahlen".. *BG Teubner, Leipzig, 1898.*

SU located in the far away from overlapped area



$$P_u(SH_i, t_{req}) = \prod_{n=1}^{m_i} P_n(0, t_{req}) = \prod_{n=1}^{m_i} (e^{-\lambda_n t_{req}})$$

SU close to the overlapped area



Evaluation and transmission in the first case

- The expected transmission time of SU service data T_E

if SU located in the far away from overlapped area then

for all spectrum holes of free and RN_z *do*

if spectum holes of RN_z *then*

$$evaluation\ T_E(SH_i) = t_{RN_z} + \frac{d_t}{P_u(m_i, t_{req}) \times R_i} + (1 - P_u(m_i, t_{req})) \times T_{L2H}$$

else

$$evaluation\ T_E(SH_i) = \frac{d_t}{P_u(m_i, t_{req}) \times R_i} + (1 - P_u(m_i, t_{req})) \times T_{L2H}$$

end if

end for

end if

Evaluation and transmission in the second case

- The expected transmission time of SU service data T_E

elseif SU close to the overlapped area then

for all spectrum holes of free and RNs(include RN_z and RN'_w) do

if spectuwm holes of RN_z then

$$\text{evaluation } T_E(SH_i) = t_{RN_z} + \frac{d_t}{P_u(m_i, t_{req}) \times R_i} + (1 - P_u(m_i, t_{req})) \times T_{L2H}$$

elseif spectrum holes of RN'_w then

$$\text{evaluation } T'_E(SH'_i) = t'_{RN'_w} + \frac{d_t}{P'_u(m'_i, t'_{req}) \times R'_i} + (1 - P'_u(m'_i, t'_{req})) \times T_{L2H} + T_{L3H}$$

else

$$\text{evaluation } T_E(SH_i) = \frac{d_t}{P_u(m_i, t_{req}) \times R_i} + (1 - P_u(m_i, t_{req})) \times T_{L2H}$$

end if

end for

end if

Evaluation and transmission in the third case

- The expected transmission time of SU service data T_E

$else$

$for\ all\ spectrum\ holes\ of\ free\ and\ RNs(include\ RN_z\ and\ RN'_w)\ do$

$if\ specturm\ holes\ of\ RN_z\ then$

$$evaluation\ T_E(SH_i) = t_{RN_z} + \frac{d_t}{P_u(m_i, t_{req}) \times R_i} + (1 - P_u(m_i, t_{req})) \times T_{L2H}$$

$elseif\ spectrum\ holes\ of\ RN'_w\ then$

$$evaluation\ T'_E(SH'_i) = t'_{RN'_w} + \frac{d_t}{P'_u(m'_i, t'_{req}) \times R'_i} + (1 - P'_u(m'_i, t'_{req})) \times T_{L2H} + T_{L3H}$$

$elseif\ spectrum\ holes\ of\ free\ and\ located\ in\ serving\ eNB\ then$

$$evaluation\ T_E(SH_i) = \frac{d_t}{P_u(m_i, t_{req}) \times R_i} + (1 - P_u(m_i, t_{req})) \times T_{L2H}$$

$else$

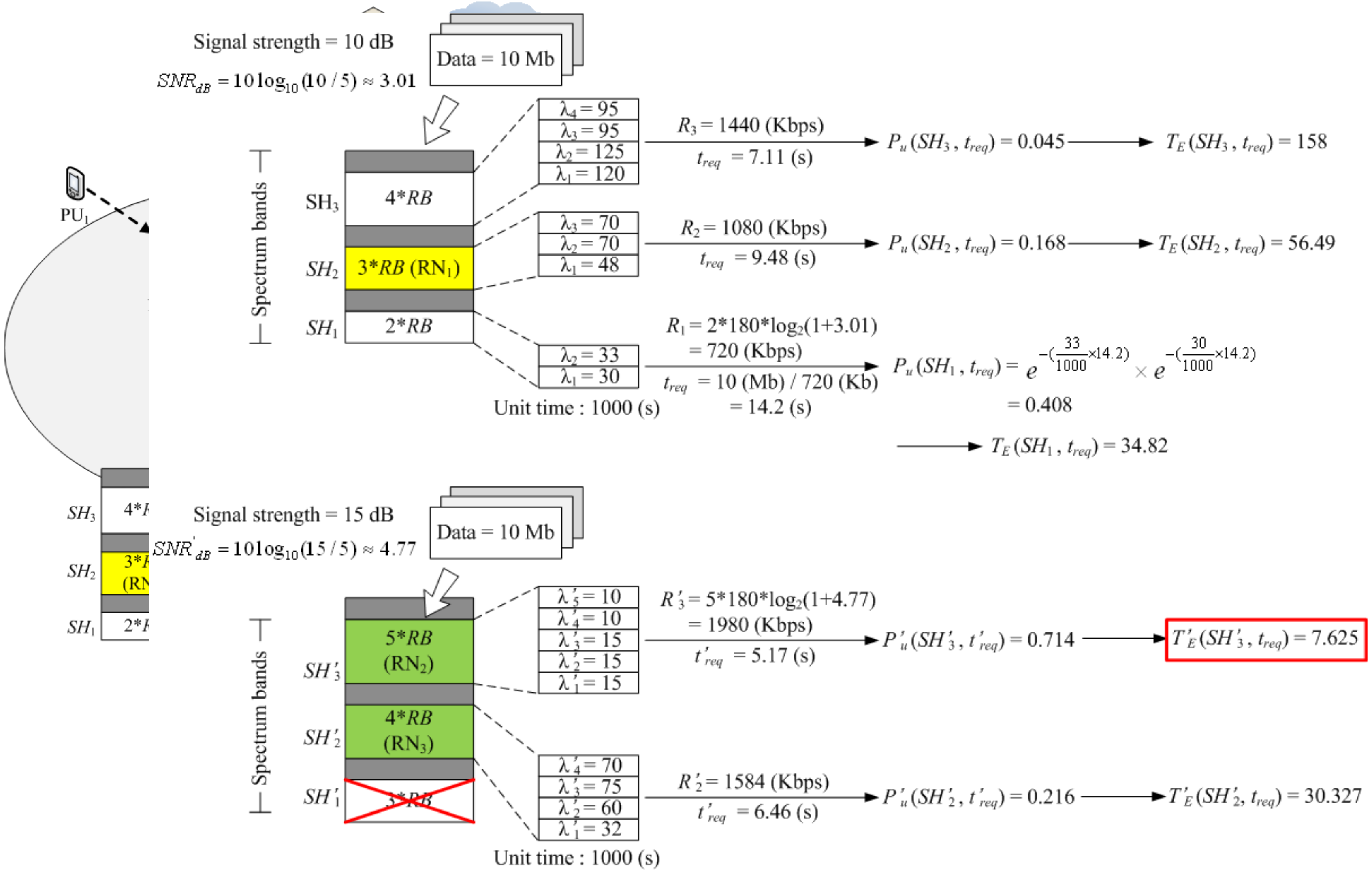
$$evaluation\ T_E(SH_i) = \frac{d_t}{P'_u(m'_i, t'_{req}) \times R'_i} + (1 - P'_u(m'_i, t'_{req})) \times T_{L2H} + T_{L3H}$$

$end\ if$

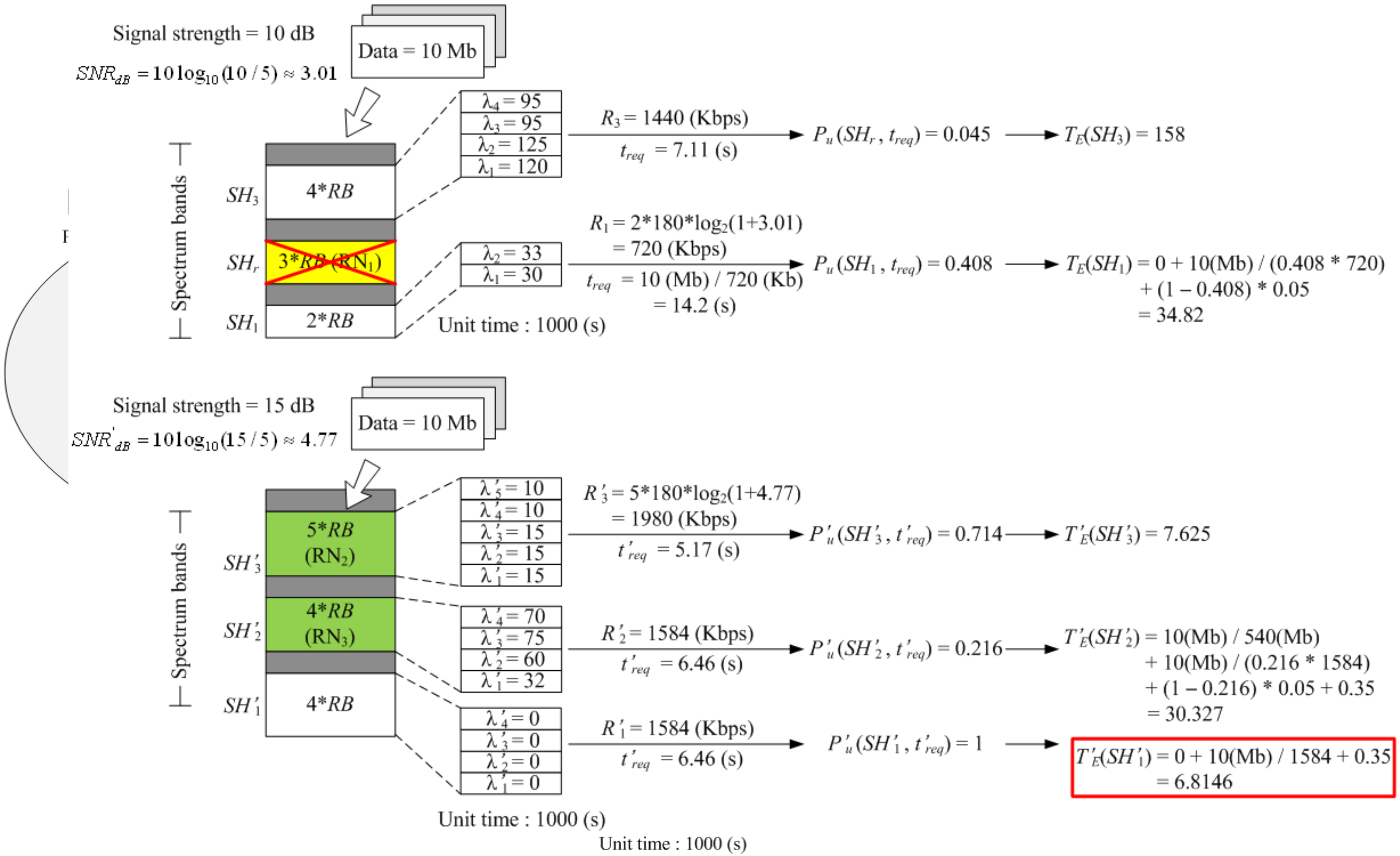
$end\ for$

$end\ if$

Example – close to the overlapped area



Example -- in the overlapped area



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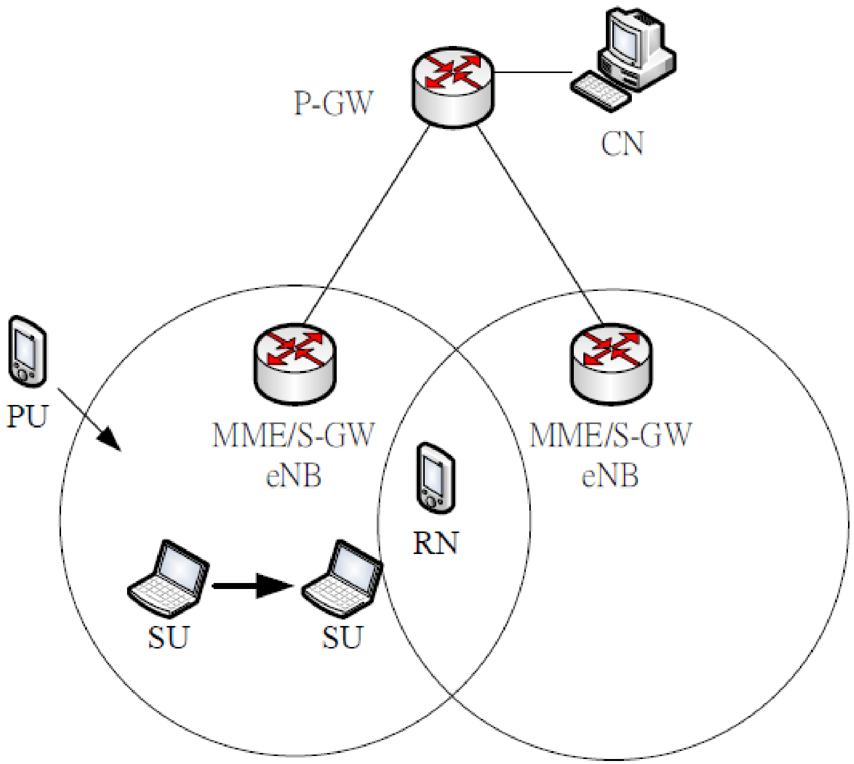
Simulation results

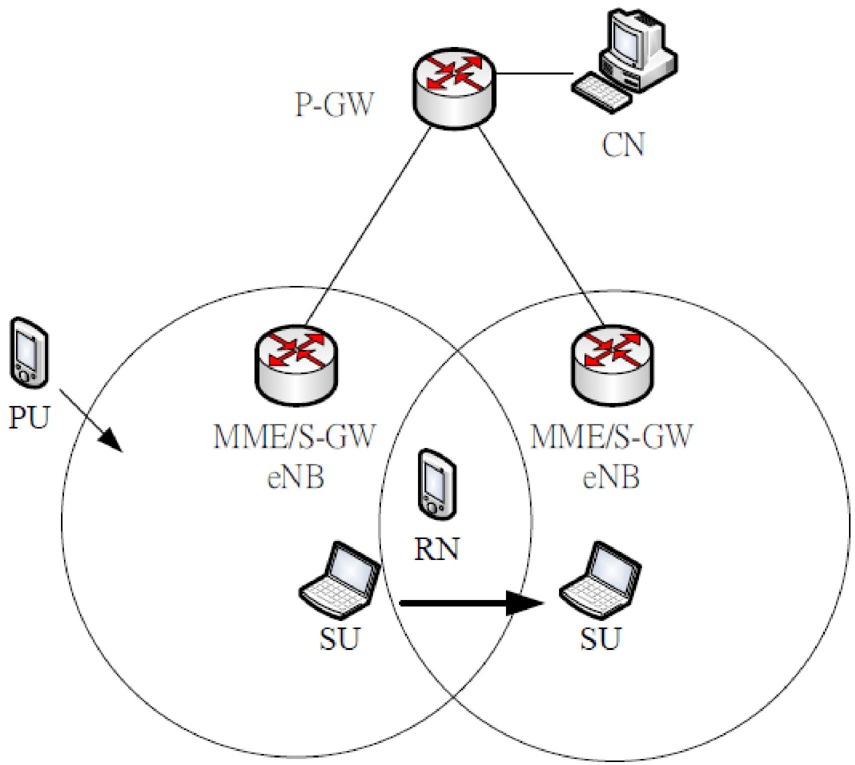
- Simulation environment
  - NS2 2.31, cognitive radio module, and EURANE module

Parameter	Value
BS transmission range	50 km
Network size	300×300 km
Secondary users sensing range	1 km
Secondary users speed	0-50 km/hr
Number secondary user	0-20
Spectrum sensing period	40 ms
Spectrum switching delay	10 ms
Transfer delay	10 ms
Handover delay	200 - 350 ms
Packet size	1500 bytes
Simulation time	100-1000 s

Simulation scenario



(a) Scenario 1



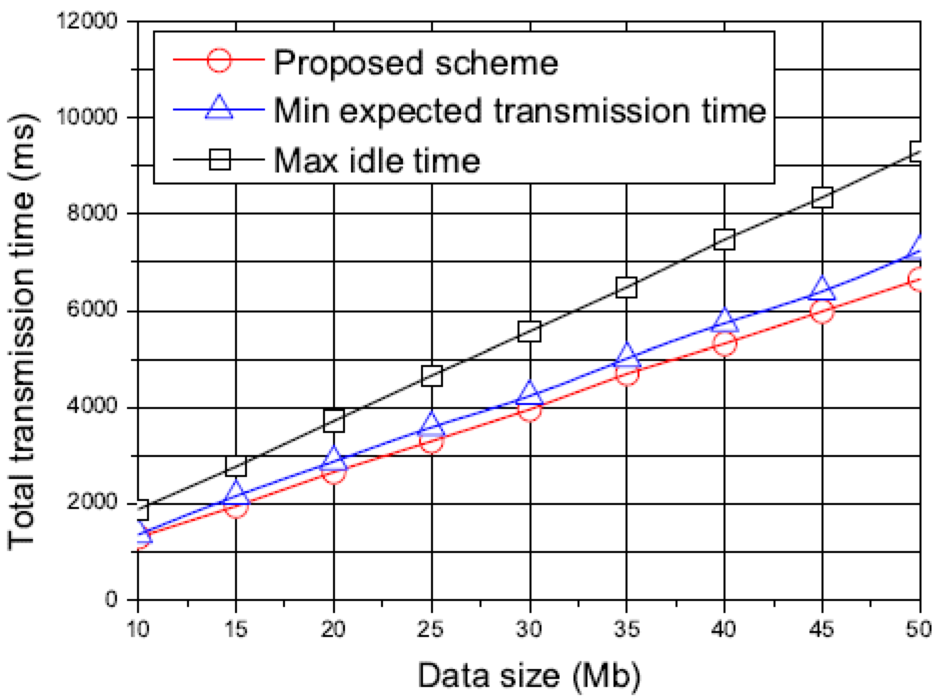
(b) Scenario 2

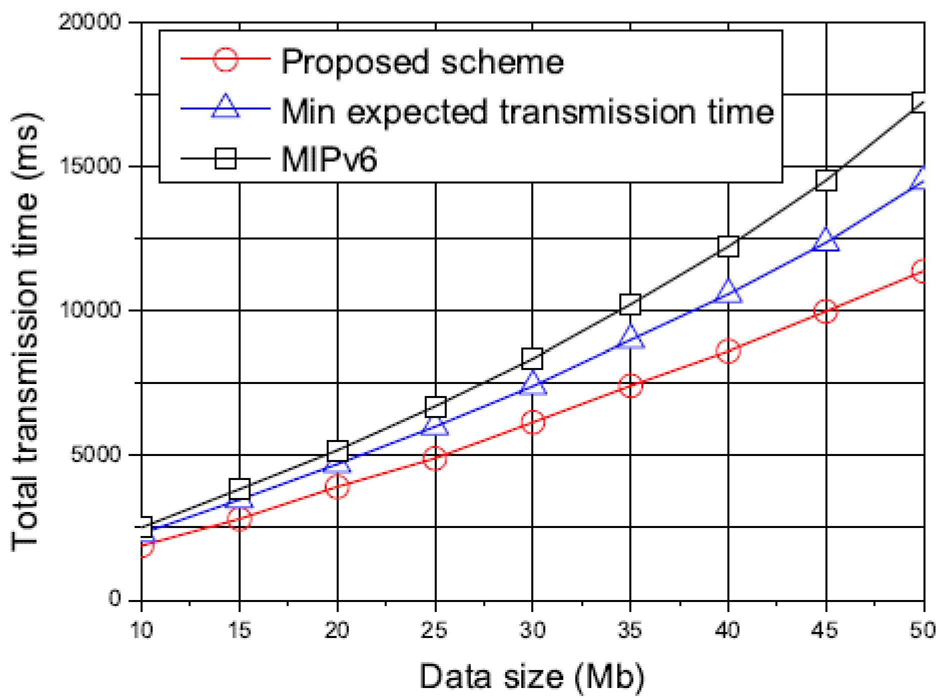
Comparison

- Scenario 1: proposed scheme, min expected transmission time and max idle time scheme
  - ✓ Total transmission time (TTT)
  - ✓ End-to-end delay (EED)
  - ✓ Throughput (TP)
  - ✓ Overhead (OH)(number of spectrum mobility)
- Scenario 2: proposed scheme, min expected transmission time and MIPv6 scheme
  - ✓ Total transmission time (TTT)
  - ✓ End-to-end delay (EED)
  - ✓ Throughput (TP)
  - ✓ Overhead (OH)(number of spectrum mobility and handover) – proposed scheme and min expected transmission time

Scheme comparison - TTT

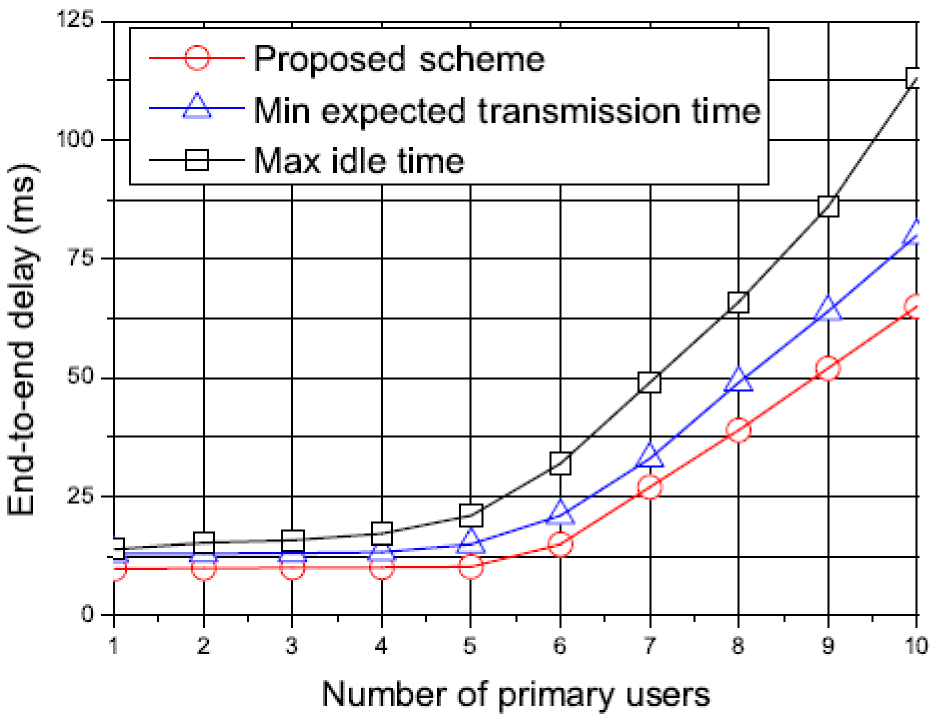
- Total transmission time vs. data in scenario 1 and 2.

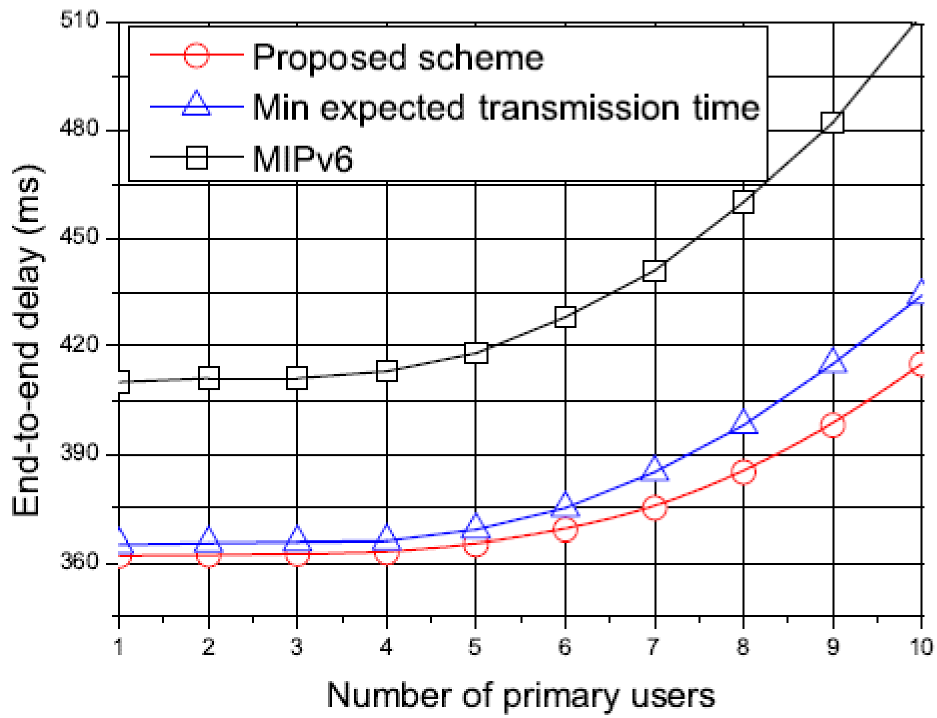




Scheme comparison - EED

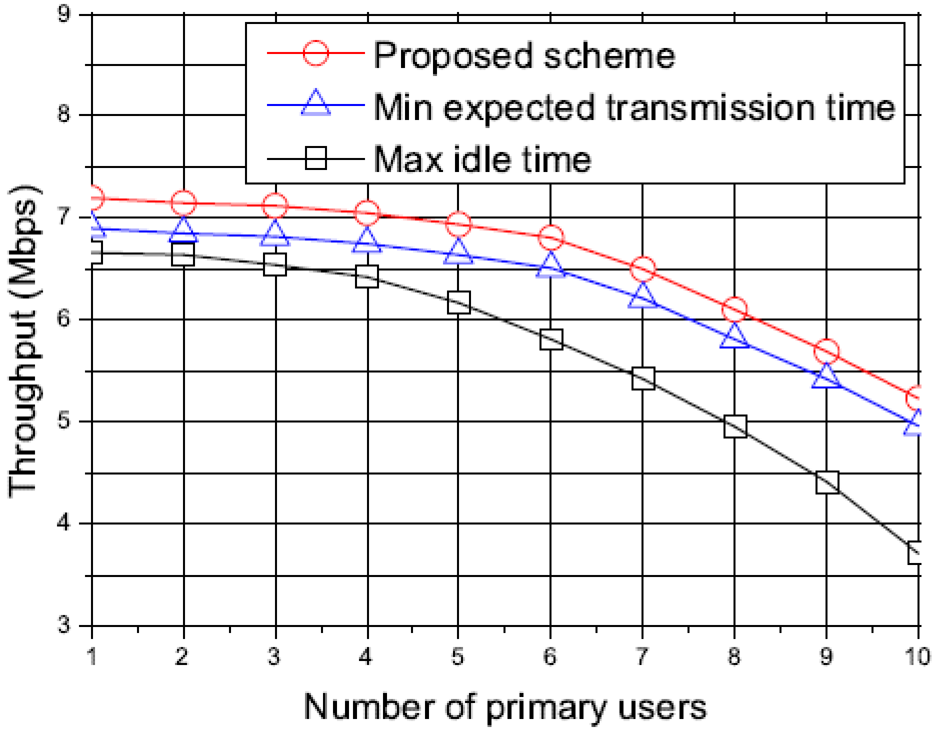
- End-to-end delay vs. number of primary users in scenario 1 and 2.

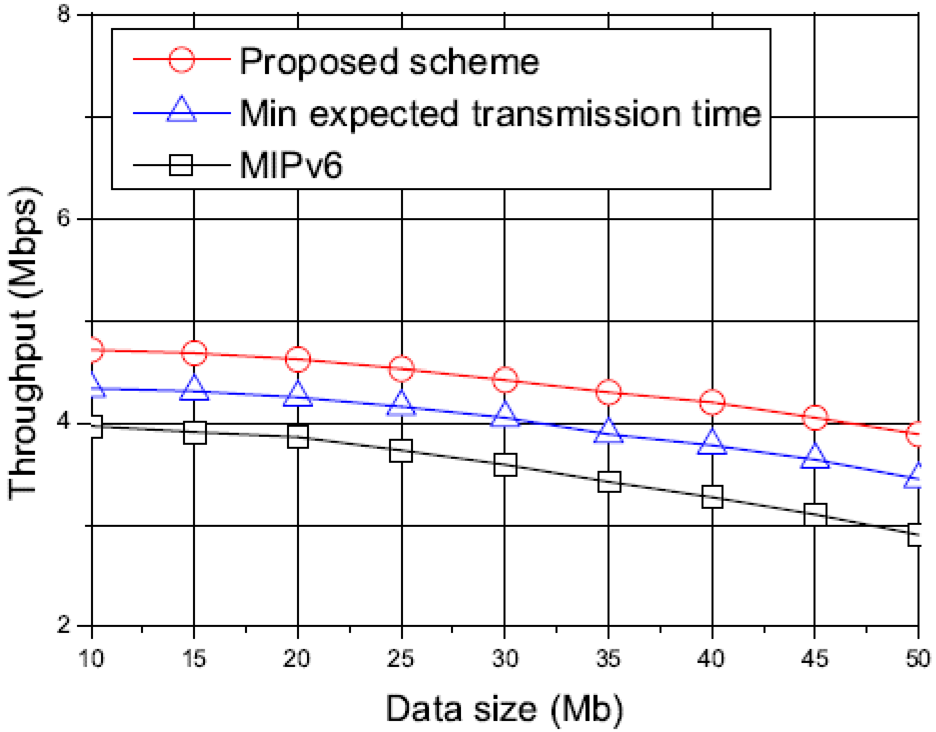




Scheme comparison - TP

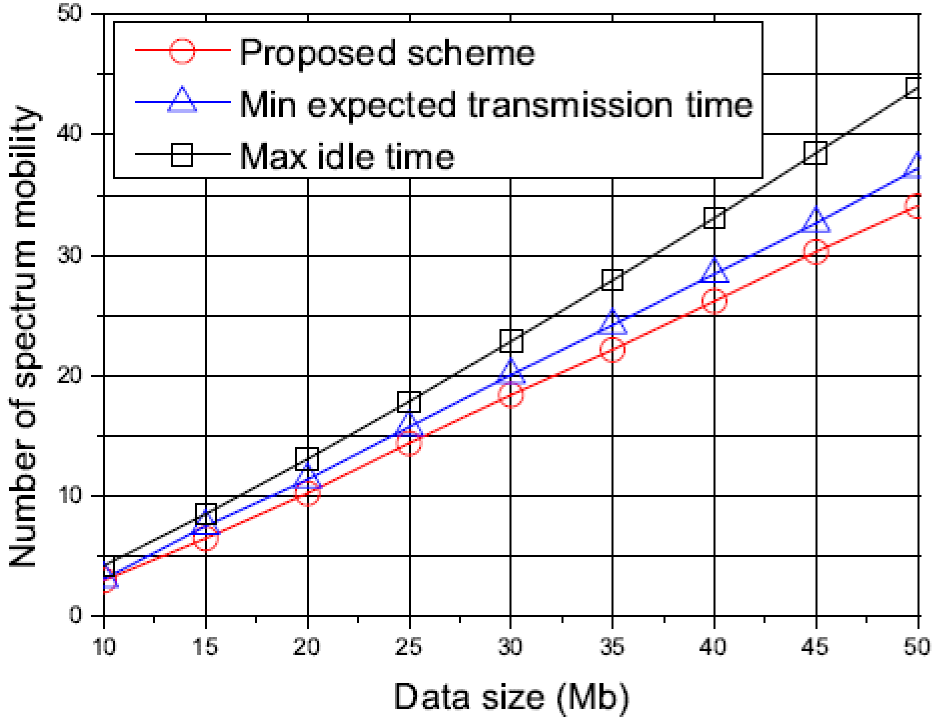
- Throughput vs. number of primary users and data size in scenario 1 and 2.

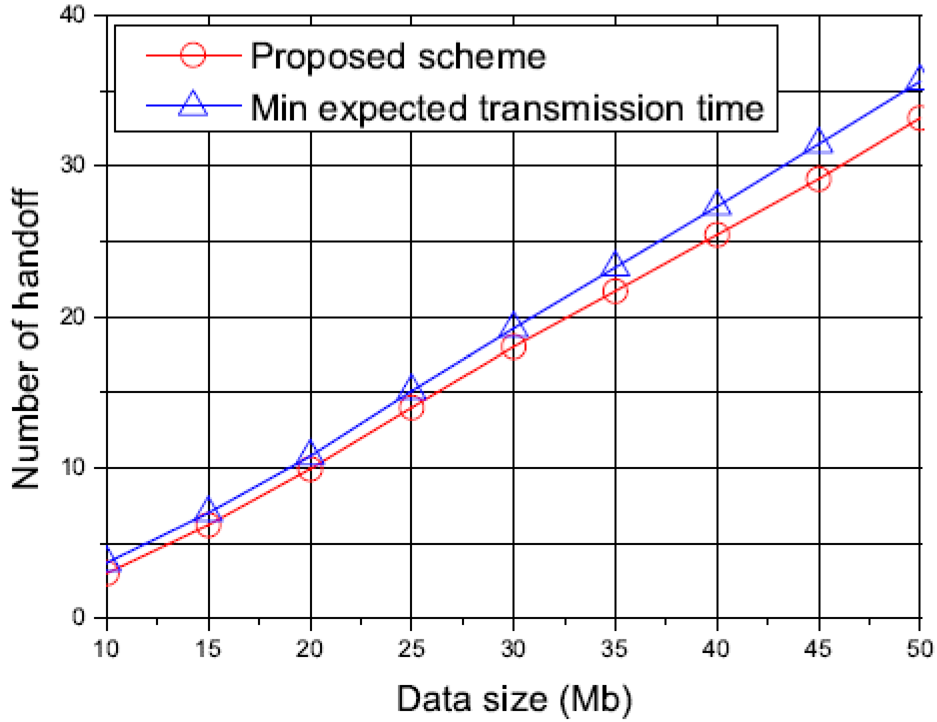




Scheme comparison - OH

- Overhead vs. data size in scenario 1 and 2.





Conclusions

- The relay-assisted expected transmission time of spectrum holes is not only for layer 2 switching the spectrum bands, but also for layer 3 to determine the handover base station with the minimum expected transmission time of spectrum hole.
- The protocol consider the remained service data size and the flexible spectrum hole size. The result of the selected spectrum hole may get more opportunity to finish the data transmission.