Chapter 9:
A Green Handover Protocol in Two-Tier OFDMA Macrocell-Femtocell Networks

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Outline

- Abstract
- Introduction
- Related work
- Preliminaries and basic idea
- A green handover protocol
- Performance analysis
- Simulation results
- Conclusions

Abstract

- Most of the power consumption of the telecommunication networks is caused by the base stations. It is important to reduce the power consumption of the base stations for the green ICT (Information and Communication Technology).
- A handover is called as a green handover if the handover is an energy-saving handover with the minimized power consumptions of base station and the UE during the handover period. The base station switches off its hardware modules for the power-saving if no active user is resident in the coverage of base station.
- In this paper, we develop a green handover protocol in two-tier OFDMA macrocell-femtocell networks based on the remainder data of a mobile host can be completely uploaded through the "will-be-wake-up" femtocell base station.

1. Introduction

- Over 90% of the power in mobile communications is consumed by base station in the radio access network.

- According to the prediction of ABI (Allied Business Intelligence) research, more than 36 million femtocells are expectedly deployed around the world by the end of 2012. Assumed that each femtocell requires a power cost of 12W, the total energy consumption of all deployed femtocells amount to 3.784×10^9 kWh/annum.

Ref: Femtocell Networks: A Survey (IEEE MCOM 2008)

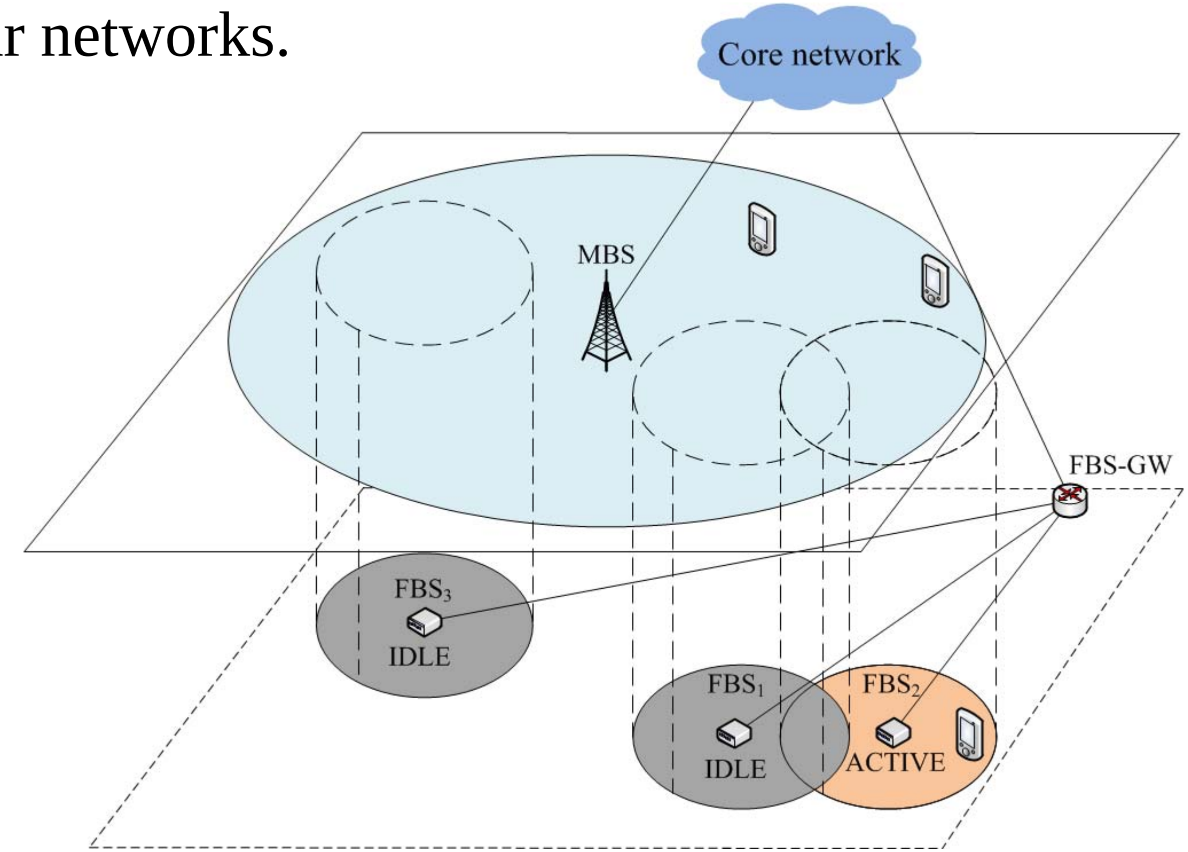
Orthogonal Frequency Division Multiple Access (OFDMA)

- The LTE/LTE-advanced and WiMax have been developed to redefine the traditional physical-layer air interface to bring the high transmission rate. With the emerging technology; such as Orthogonal Frequency Division Multiple Access (OFDMA)

- In the LTE/LTE-advanced system, the total spectrum is partitioned into several pieces of spectrum which is denoted as “resource block (RB)” or “tile”. The sub-band is called as sub-channel in the WiMAX system.

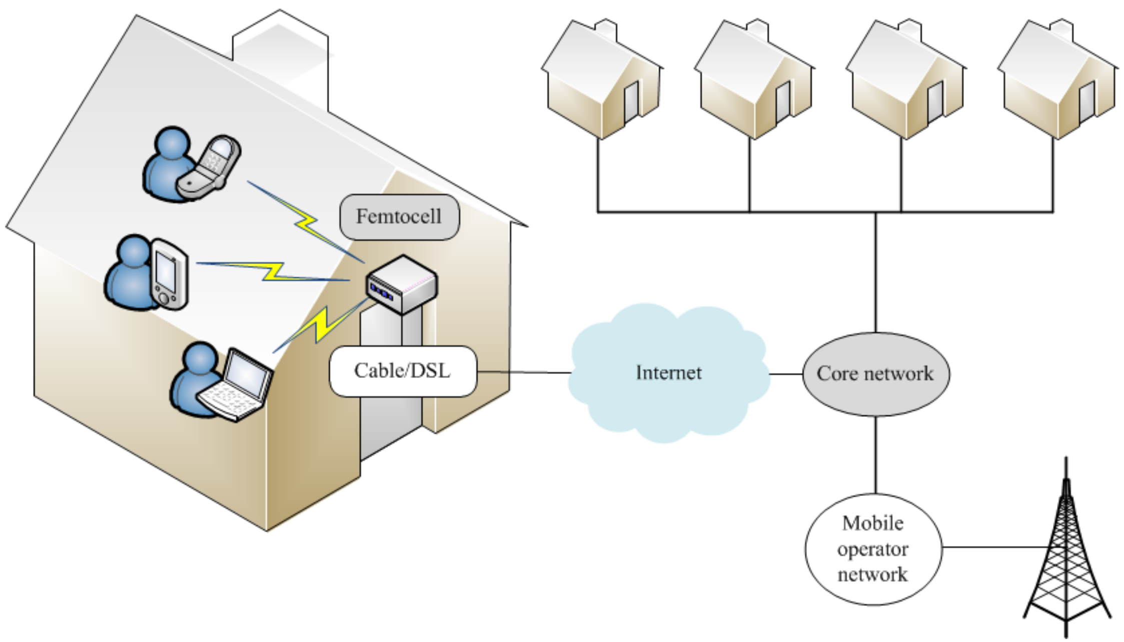
Two-tier macrocell-femtocell networks

- A hierarchical radio access network which is a two-tier macrocell/femtocell network. The macrocell base station refers to MBS and the femtocell base station refers to FBS in the two-tier cellular networks.



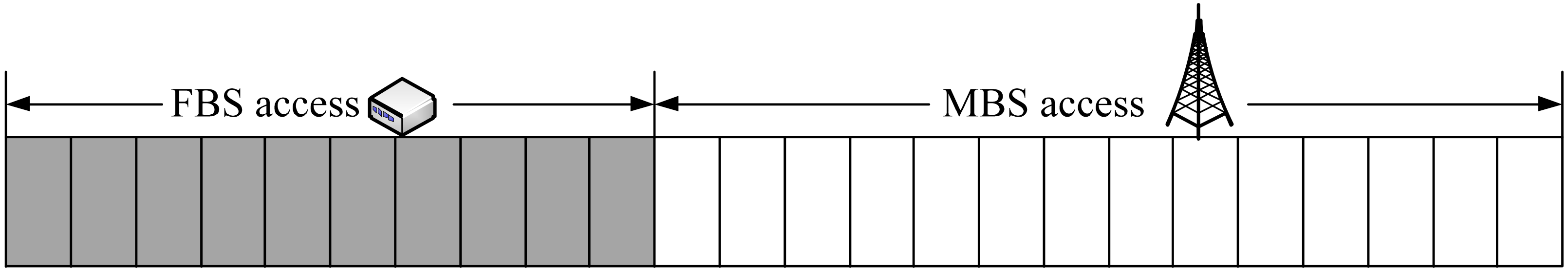
Femtocell overview

- The features of femtocell:
  - low power
  - low cost
  - user-deployed
  - small coverage range (e.g. 30 ~ 50 meters in diameter)

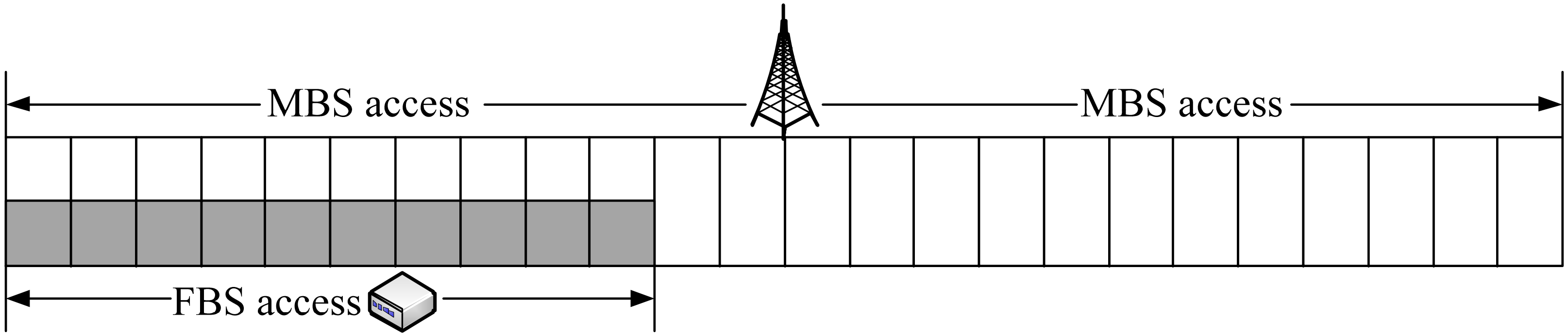


Ref: Femtocell Access Control Strategy in UMTS and LTE (IEEE MCOM 2009)

Channel operation



(a) Dedicated channel operation.



(b) Co-channel operation.

Ref: On Resource Reuse for Cellular Networks with Femto- and Macrocell Coexistence (IEEE Globecom 2010)

2. Related work

- Energy based
  - I. Ashraf, L. T. W. Ho, H. Claussen, "Improving **Energy** Efficiency of Femtocell Base Stations via User Activity Detection" IEEE Wireless Communications and Networking Conference (**WCNC 2010**)

- Signal strength based
  - J. M. Moon, D. H. Cho, "Novel **Handoff** Decision Algorithm in Hierarchical Macro/Femto-Cell Networks" *IEEE Wireless Communications and Networking Conference* (**WCNC 2010**)

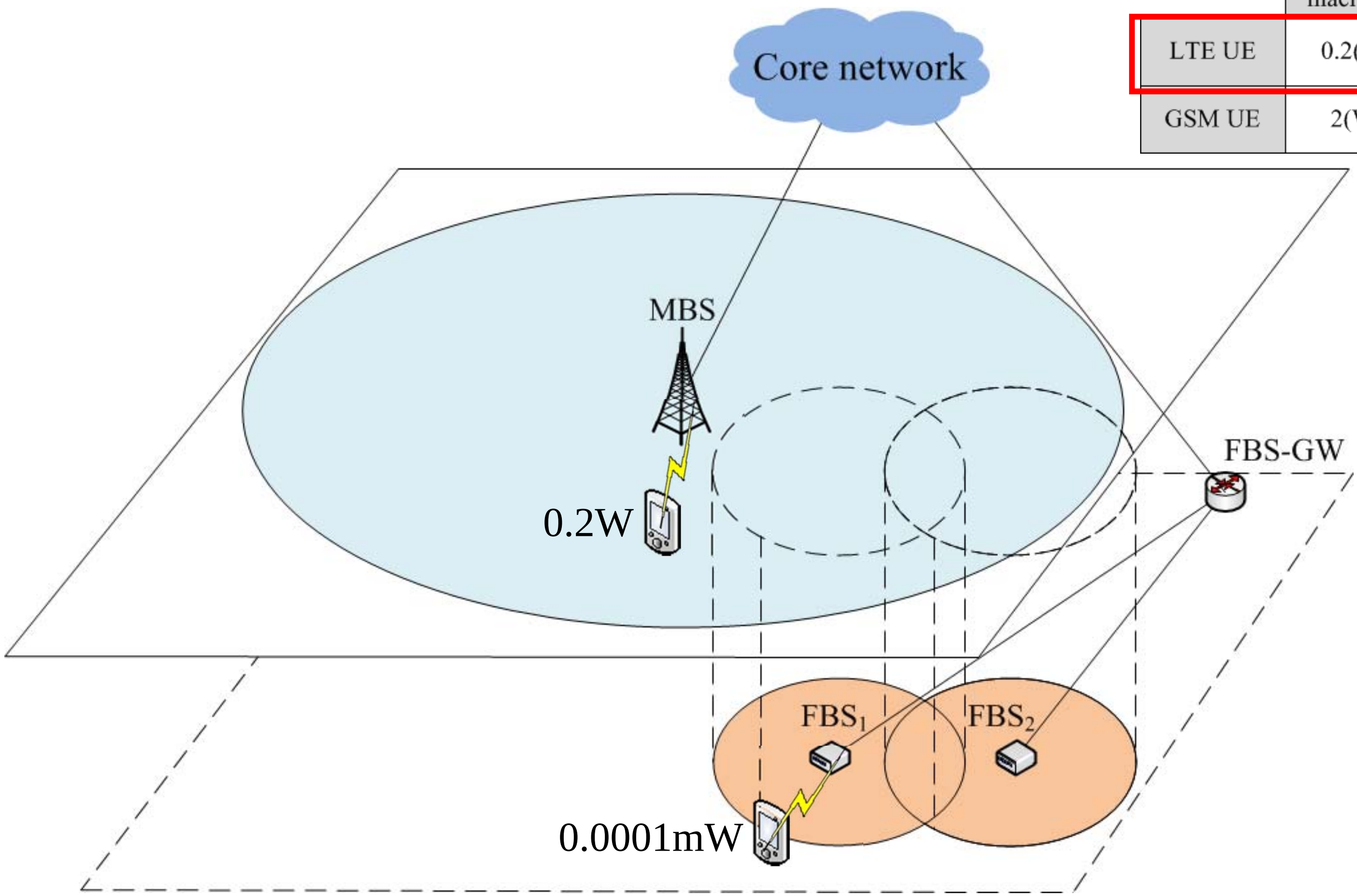
2. Related work

- Velocity based
  - S. Wu, X. Zhang, R. Zheng, Z. Yin, Y. Fang, D. Yang, "**Handover** Study Concerning Mobility in the Two-hierarchy Network" *IEEE Vehicular Technology Conference* (**VTC 2009-Spring**)
  - A. Ulvan, R. Bestak, M. Ulvan, "The Study of **Handover** Procedure in LTE-based Femtocell Network" *IEEE Wireless and Mobile Networking Conference* (**WMNC 2010**)
  - H. Zhang, X. Wen, B. Wang, W. Zheng, Y. Sun, "A Novel **Handover** Mechanism between Femtocell and Macrocell for LTE based Networks" *International Conference on Communication Software and Networks* (**ICCSN 2010**)

Motivation

	Active	Idle	Power saving
Femtocell	10.2(W)	6(W)	4.2(W)

	Connect to macrocell	Connect to femtocell	Power saving
LTE UE	0.2(W)	0.0001m(W)	≈ 0.2(W)
GSM UE	2(W)	3.2m(W)	1.9968(W)



Ref: Energy and Cost Impacts of Relay and Femtocell deployment in LTE-Advanced (IET Communications 2011), 3GPP TS 36.101

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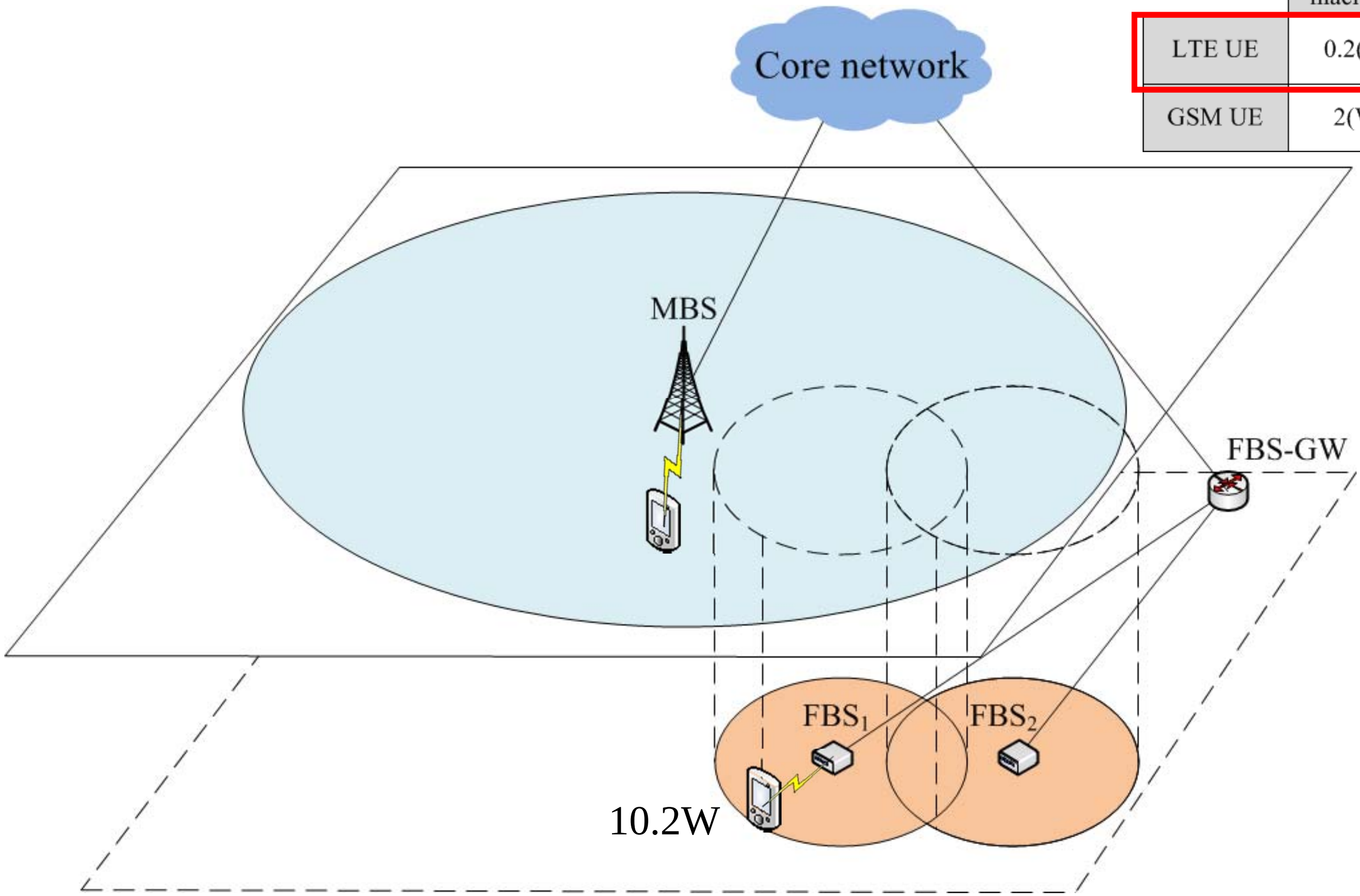

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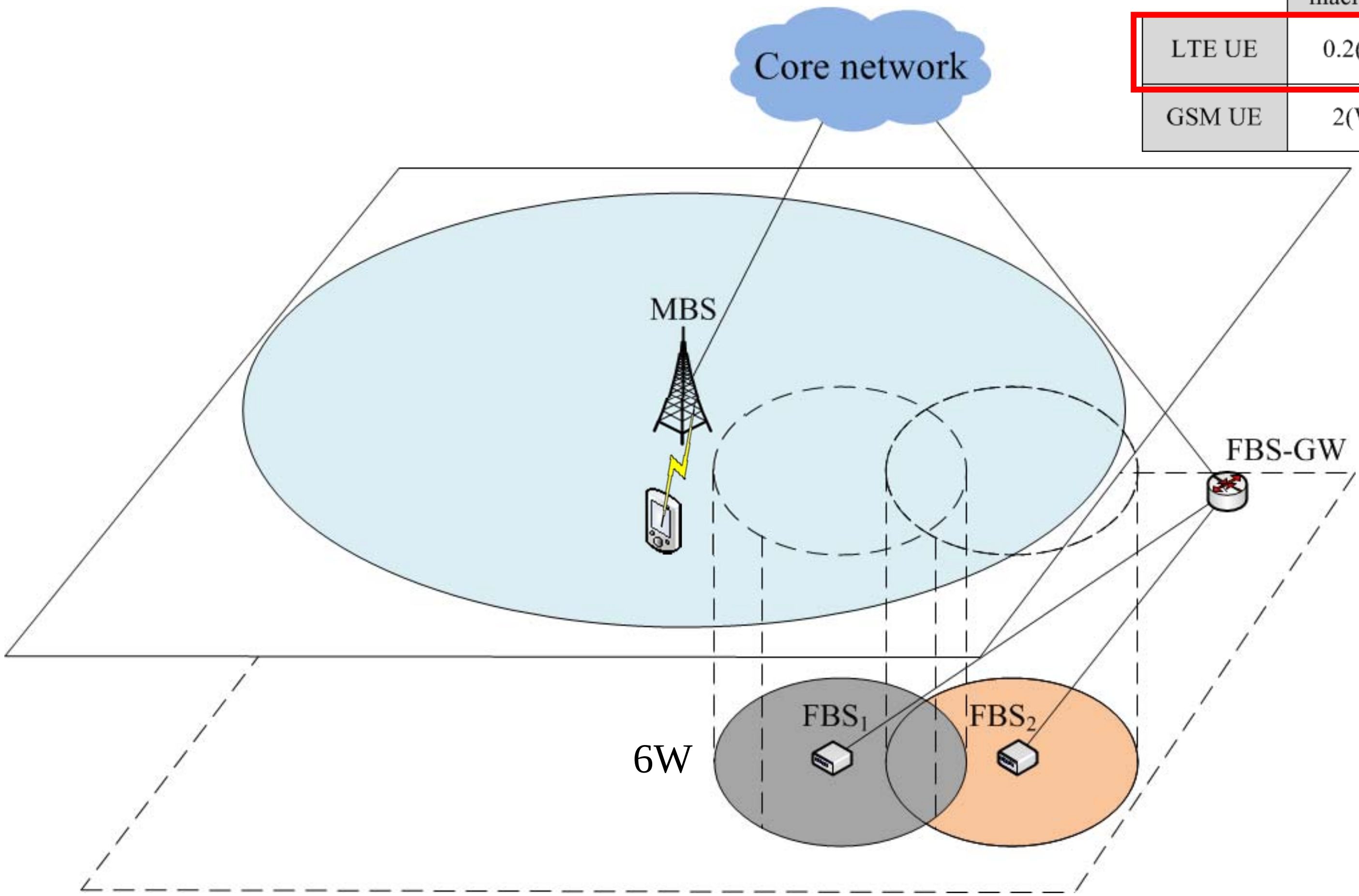
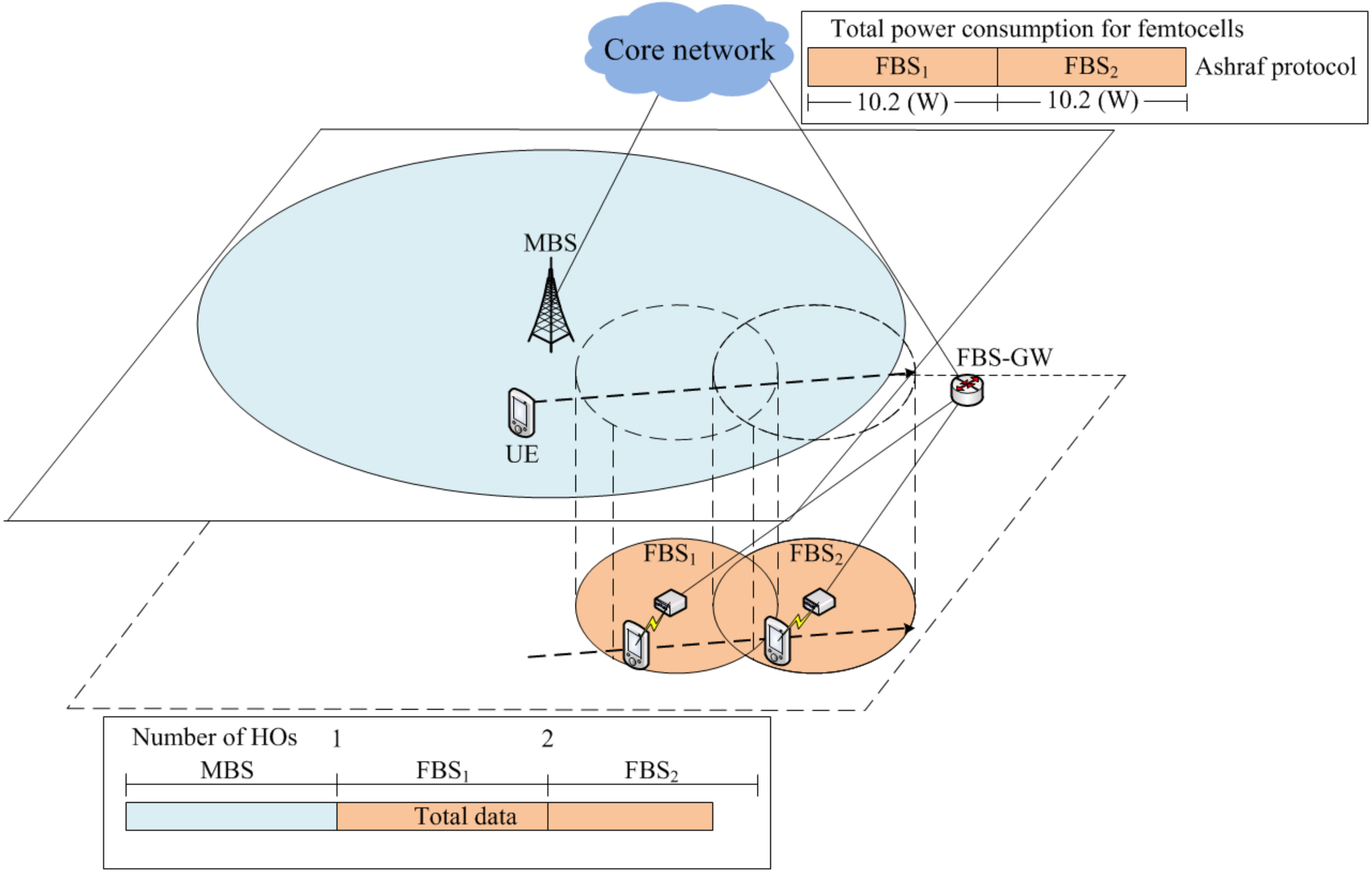


Ref: Energy and Cost Impacts of Relay and Femtocell deployment in LTE-Advanced (IET Communications 2011), 3GPP TS 36.101

Comparison with existing protocol (WCNC 2010)



Ref: Improving Energy Efficiency of Femtocell Base Stations via User Activity Detection (IEEE WCNC 2010)

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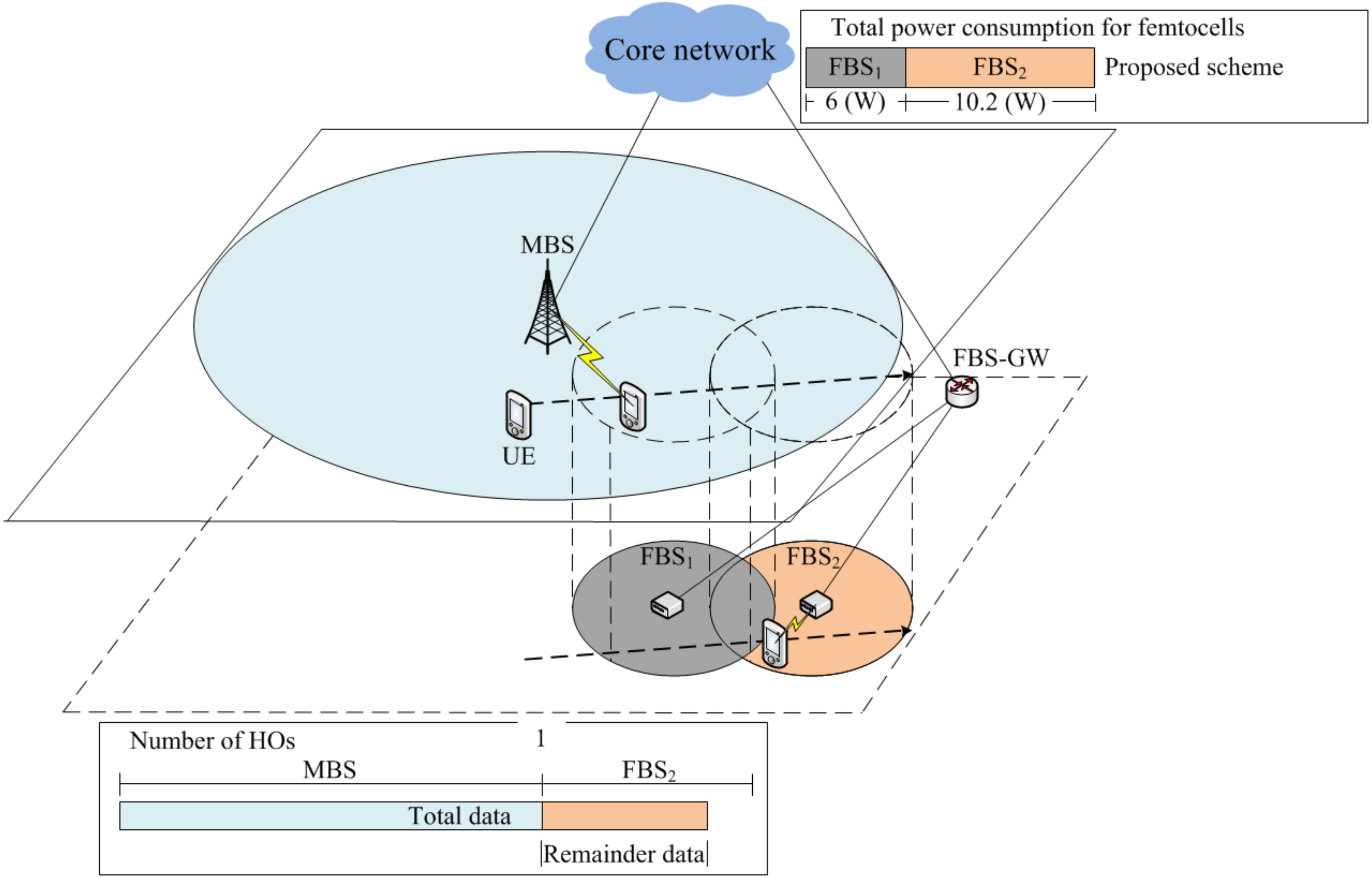
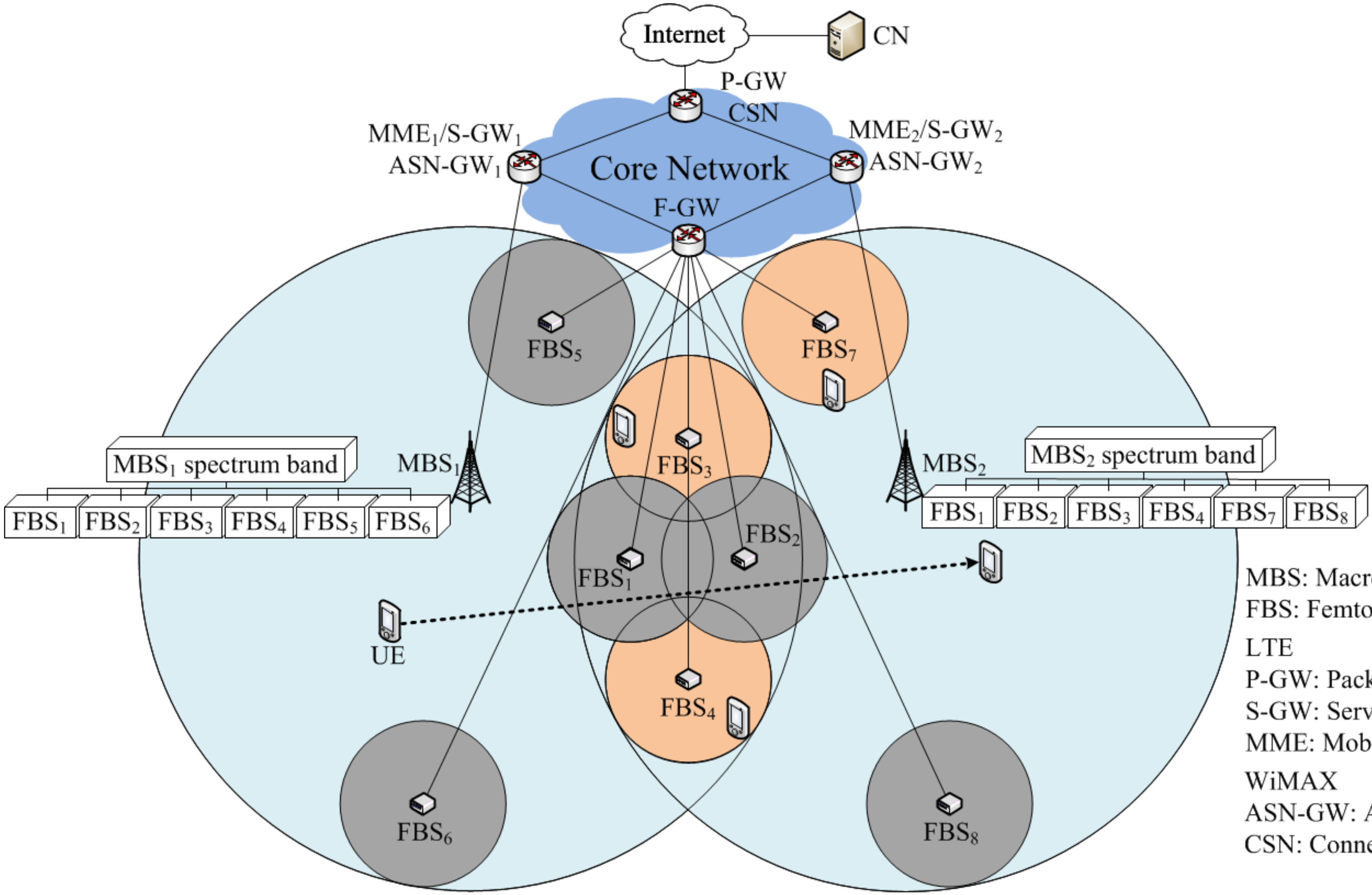


Objective

- The overall system power consumption of the two-tier macrocell-femtocell network, is minimized by intelligently switching on/off its radio communication and associated processing, which aims to keep the femtocell at the IDLE mode as far as possible,
- A handover decision protocol is designed to reduce the handover number and the signaling cost during the UE mobility.

System model

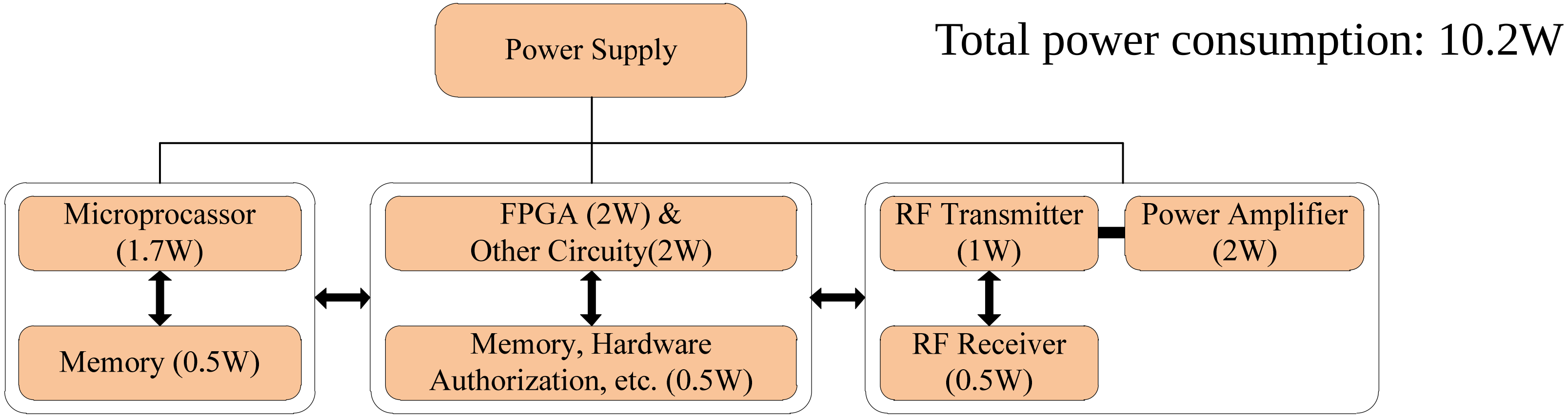


MBS: Macro base station
FBS: Femto base station

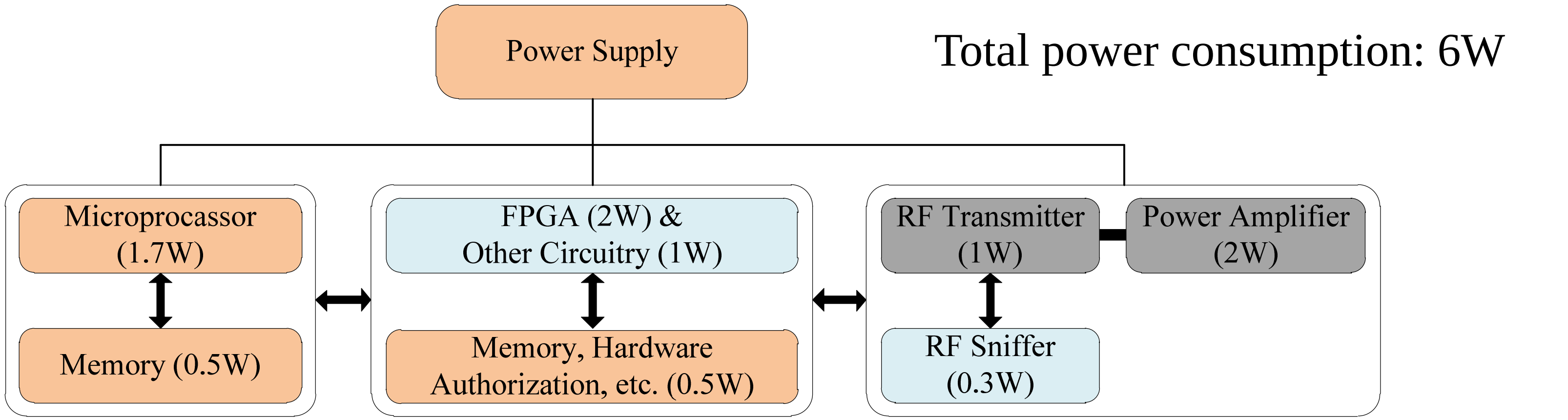
LTE
P-GW: Packet data network gateway
S-GW: Serving gateway
MME: Mobility management entity

WiMAX
ASN-GW: Access service network gateway
CSN: Connectivity service network

Femtocell hardware



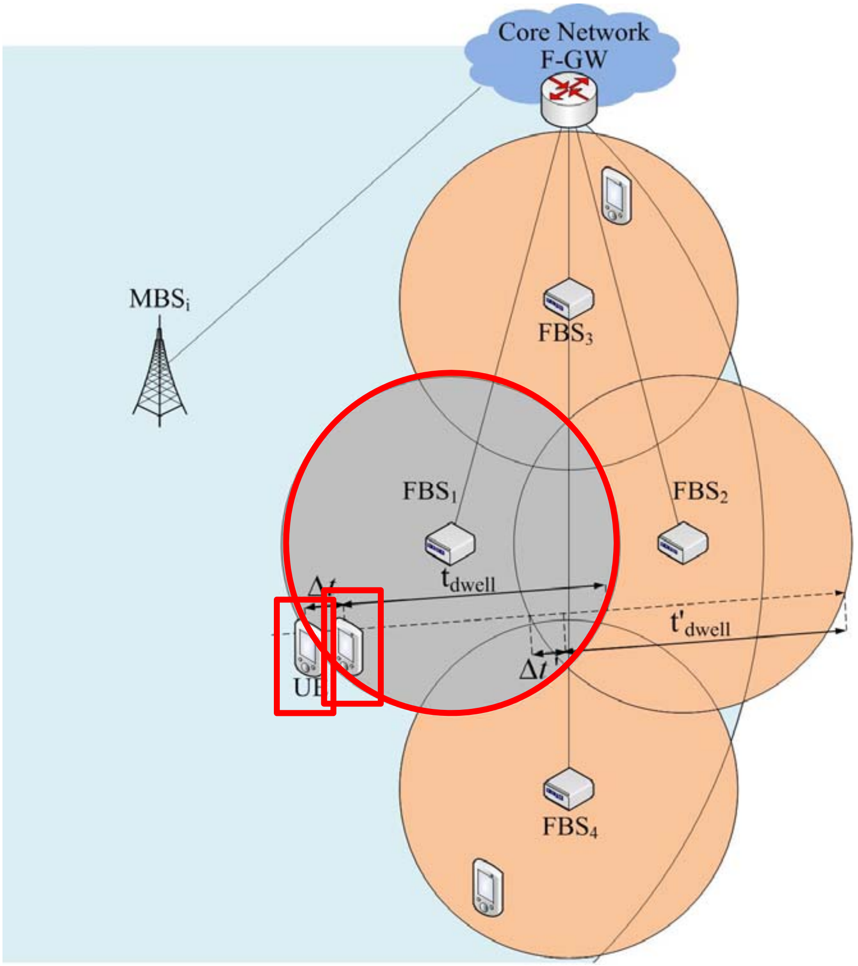
(a) ACTIVE mode



(b) IDLE mode

Ref: Improving Energy Efficiency of Femtocell Base Stations via User Activity Detection (IEEE WCNC 2010)

Basic Idea



It is observed that a FBS switches from IDLE mode into ACTIVE mode only if $t_{\text{dwell}} \geq t_{\text{expected}}$

But if , $t_{\text{dwell}} < t_{\text{expected}}$ then the FBS should not be wake up from the IDLE mode, and the UE still connects with the macro BS and do not perform the handover procedure.

Contribution

- A new green handover procedure is developed to minimize the power consumption of femtocells and the handover cost. The contribution of this paper is
  - The overall system power consumption of the two-tier macrocell-femtocell network, is minimized by intelligently switching on/off its radio communication and associated processing.
  - A handover decision protocol is designed to reduce the handover number and the signaling cost during the UE mobility.

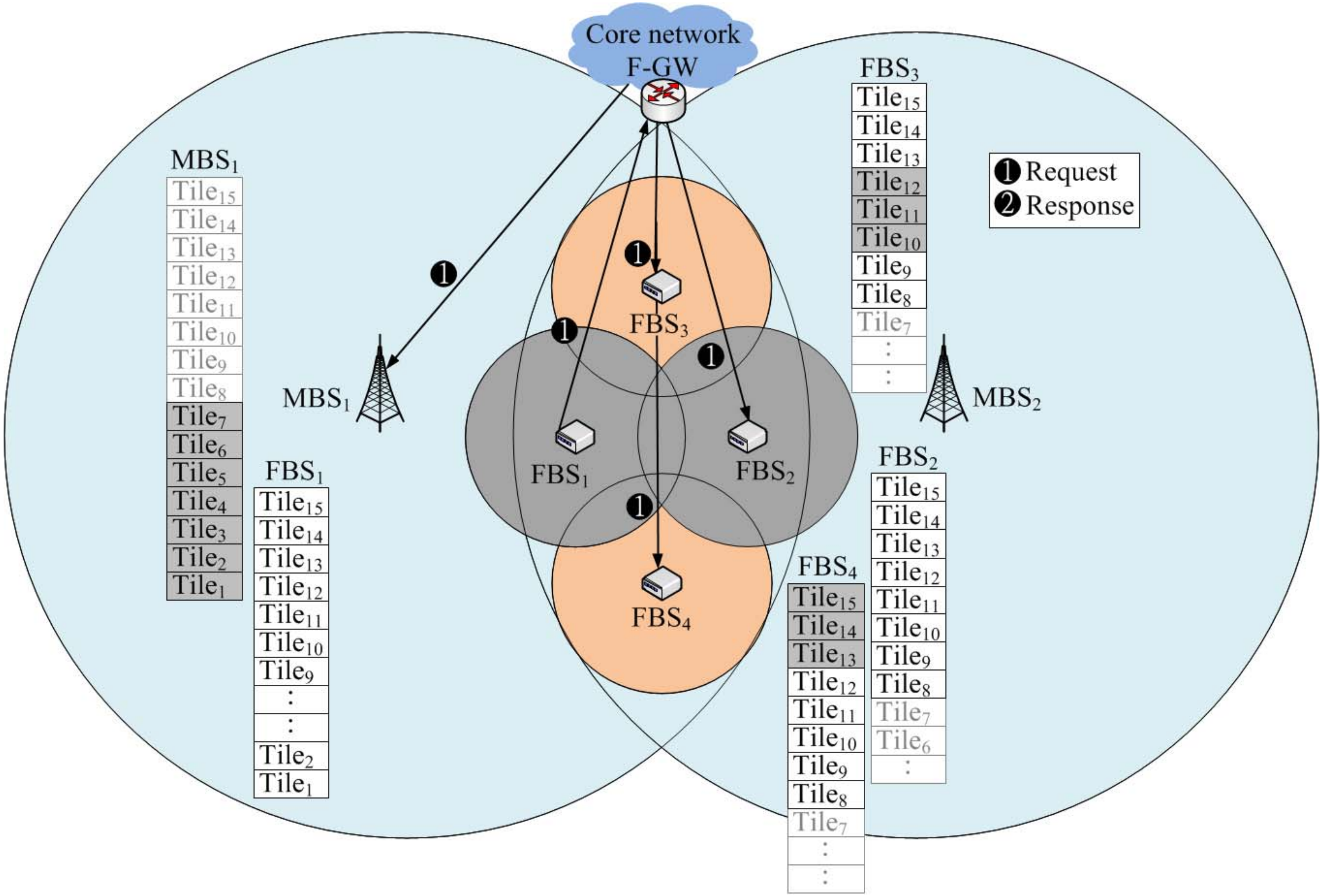
A Green Handover Protocol in Two-Tier OFDMA Macrocell-Femtocell Networks

4. A green handover protocol

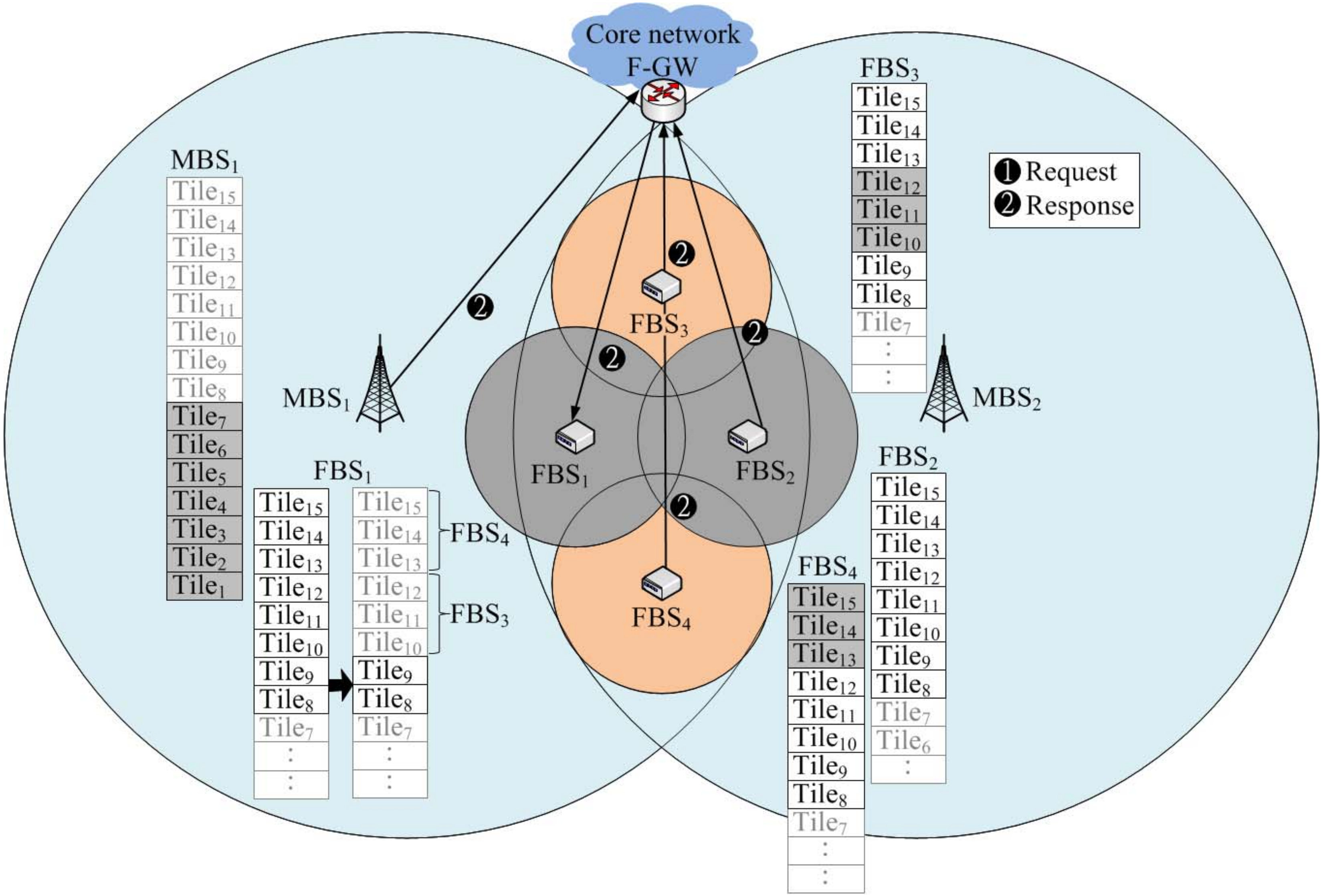
- The main function of the green handover protocol is to make an intelligent decision of accurately wake-up the FBS from IDLE mode into ACTIVE mode at the right time and at the right place. This is mainly based on the prediction of the dwell time and average expected transmission time of the UE.

- The developed protocol consists of three phases:
  - Free spectrum configuration phase
  - Transmission time estimation phase
  - Green handover decision phase

Free spectrum configuration phase



Free spectrum configuration phase



Transmission time estimation phase

- This phase is divided into three parts:
  - The dwell time
  - The required bandwidth
  - The average expected transmission time

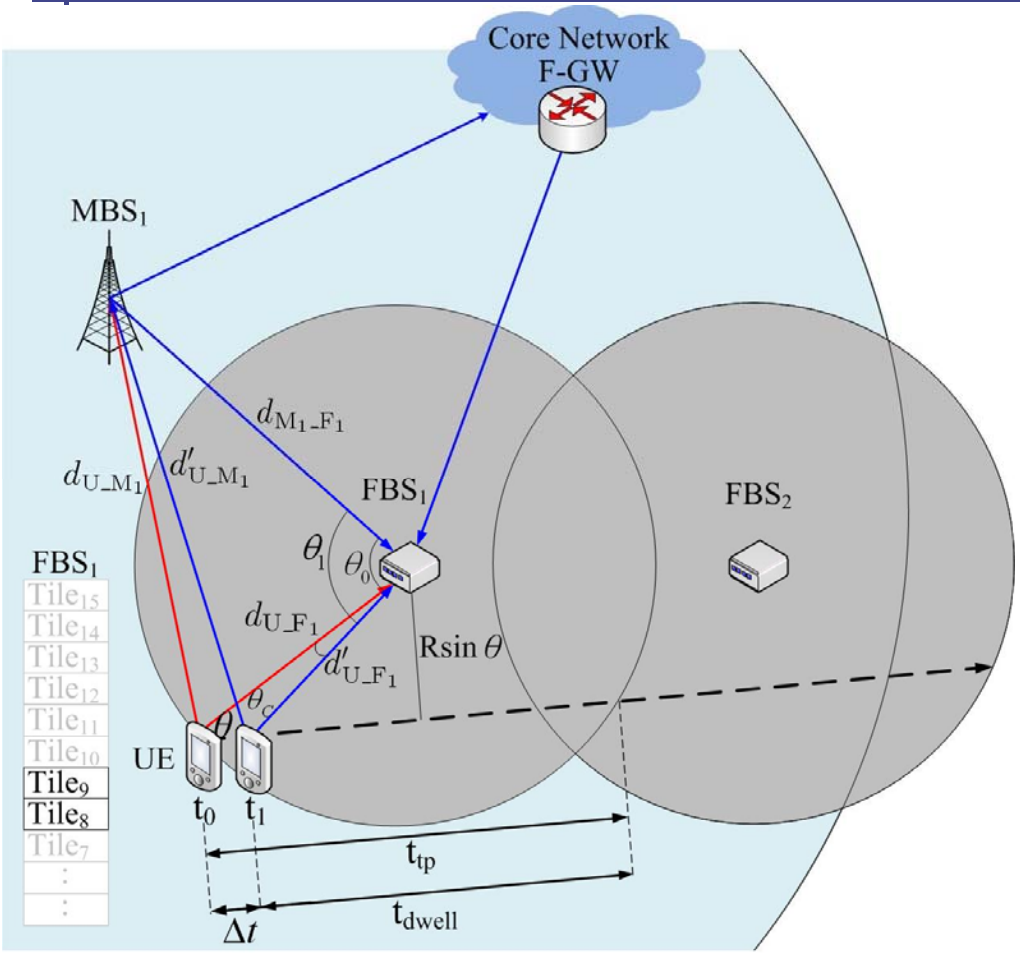
- Shannon theorem:

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

- Path loss model:

$$PL = 38.46 + 20\log_{10} d$$

Dwell time



$$\theta_C = \theta_1 - \theta_0$$

$$\theta = \cos^{-1} \frac{d^2_{\mathrm{U\_F_1}} + d'^2_{\mathrm{t_0\_t_1}} - d'^2_{\mathrm{U\_F_1}}}{2 d_{\mathrm{U_1\_F_1}} d'_{\mathrm{t_0\_t_1}}}$$

$$\alpha = \frac{\int_{d_{\mathrm{UE\_FBS_1}}}^{d'_{\mathrm{UE\_FBS_1}}} SNR_{\mathrm{UE}} - 38.46 + 20 \log_{10}(d)}{t_1 - t_0}$$

$$SNR_{\mathrm{MAX}} = SNR_{\mathrm{UE}} - (38.46 + 20 \log_{10}(R \sin\theta))$$

$$t_{\mathrm{tp}} = 2 \times \frac{SNR_{\mathrm{MAX}}}{\alpha}$$

$$t_{\mathrm{tp}} - \Delta t = t_{\mathrm{tp}} - (\mathrm{t}_{\mathrm{i+1}} - t_{\mathrm{i}})$$

Ref: 3GPP TR 36.814 V9.0.0.0 (2010-03)

Required bandwidth

- An IDLE initially allocates $l = 1$ tile for the UE.

$$\mathrm{E}_{\mathrm{B}}^{\mathrm{UE}}(\phi) = \mathrm{E}_{\mathrm{C}}^{(\mathrm{UE},1)}(\phi) = \delta$$

  - If $l \neq 1$, the effective capacity is

$$\mathrm{E}_{\mathrm{C}}^{(\mathrm{UE},l)}(\phi) = l\omega_l \mathrm{E}_{\mathrm{C}}^{(\mathrm{UE},1)}(l\omega_l\phi)$$

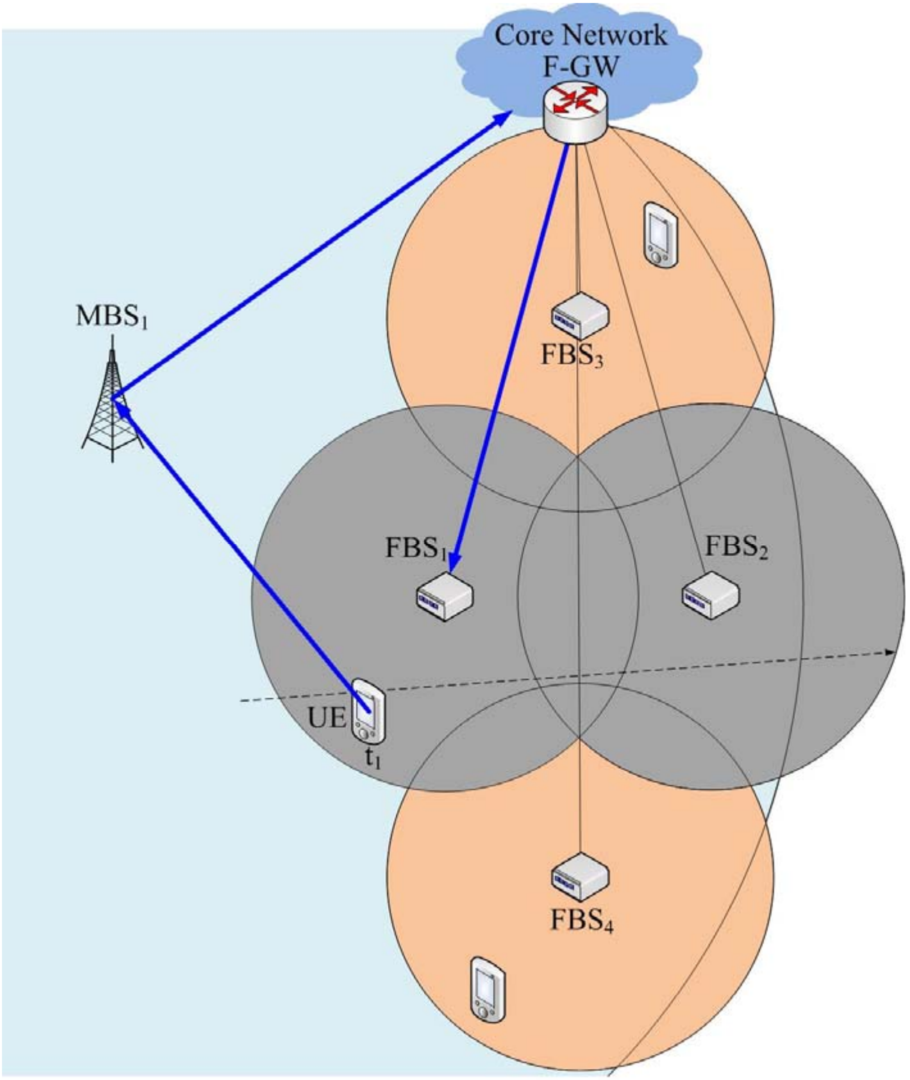
- The delay bound probability:

$$\Pr\{Delay > t_{\mathrm{dwell}}\} = e^{-\phi\delta t_{\mathrm{dwell}}}$$

- If $\Pr\{Delay > t_{\mathrm{dwell}}\} = e^{-\phi\delta t_{\mathrm{dwell}}} > \varepsilon^{\mathrm{UE}}$, then l is increased.

Ref: Cognitive Radio Resource Management for QoS Guarantees in Autonomous Femtocell Networks (IEEE ICC 2010)

Average expected transmission time



- The average expected transmission time:

$$t_{\text{expected}} = \frac{D_{\text{remainder}}}{R^{UE}_{\text{average}}}$$

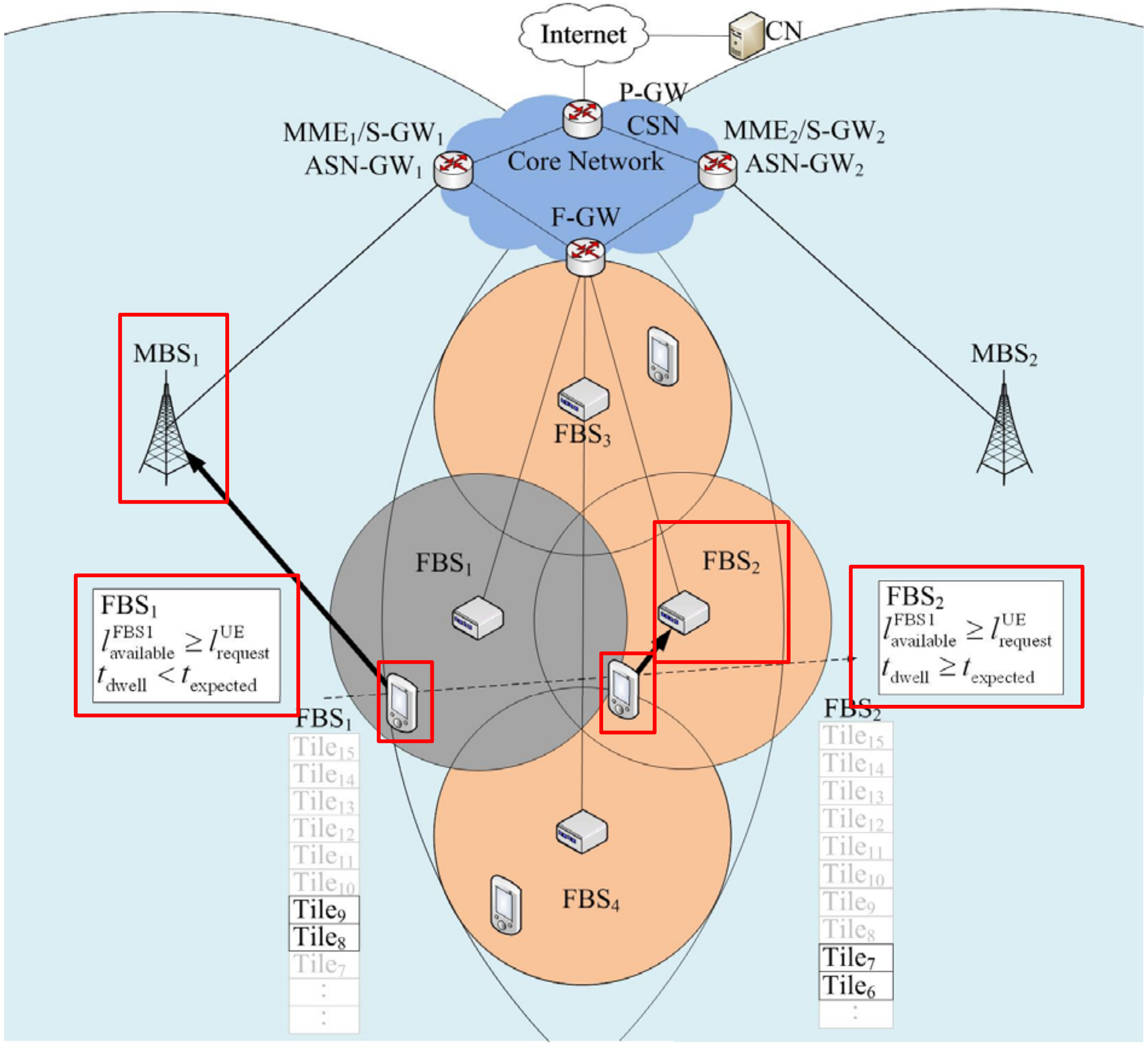
- The average transmission rate:

$$R^{UE}_{\text{average}} = l_{\text{required}} \times \log_2 (1 + RSSI_{\text{dB}})$$

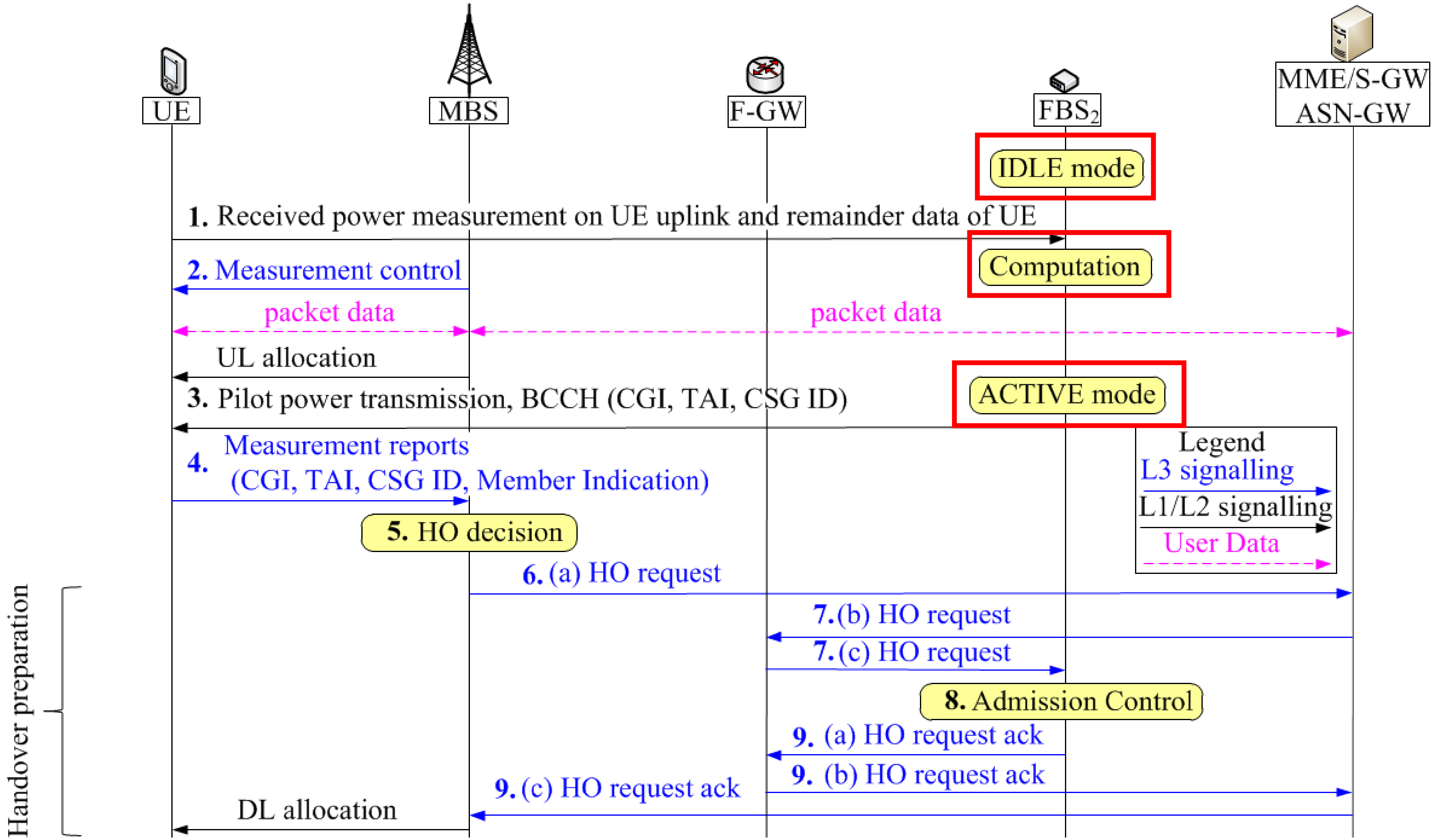
$$RSSI_{\text{dB}} = SNR_{\text{FBS}_j} - PL_{\text{average}},$$

$$PL_{\text{average}} = \frac{1}{2R} \int_0^{2R} 38.46 + 20 \log_{10}(d) d(d)$$

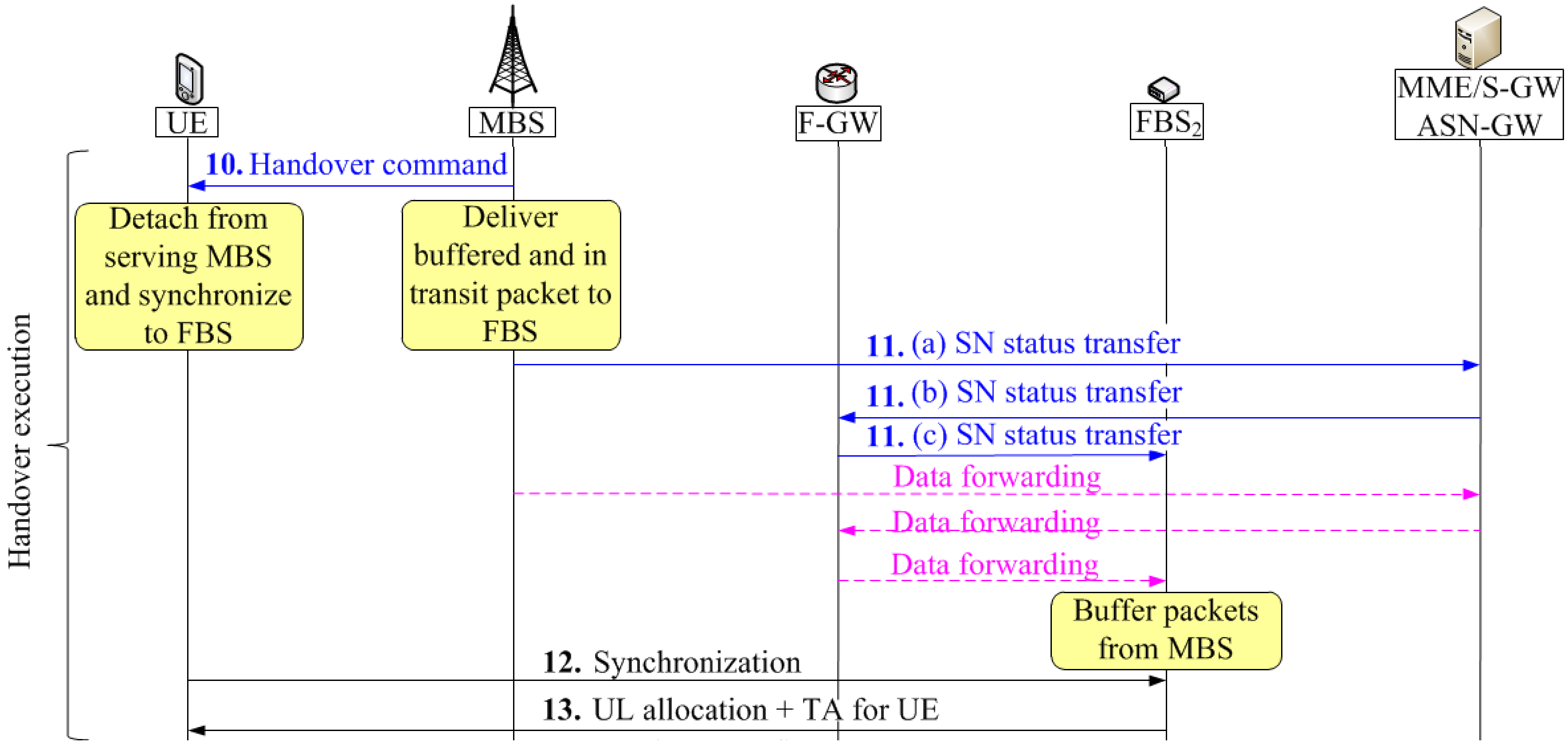
Green handover decision phase



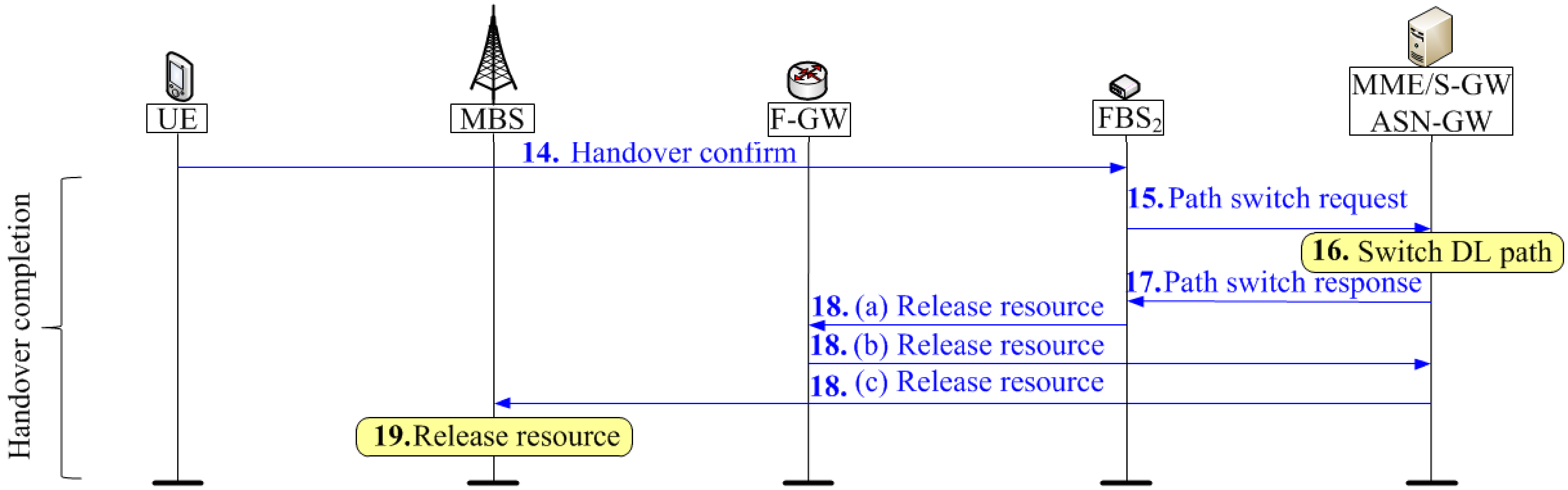
Handover preparation



Handover execution



Handover completion



5. Performance analysis

- **Lemma 1**: The average energy consumption for the data transmission of an UE during an in-bound mobility of Ashraf protocol is

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

$$P(k,T_j) = P(0,T_j) = P_{\mathrm{n_j}} = e^{-\lambda_j T_j}$$

$\lambda_j = \frac{1}{t_j}$

T_j is equal to t_{tp}

$$E_{\mathrm{A}} = E + \frac{1}{n}\sum_{j=1}^{n}(e^{-\lambda_j T_j} \times E_{\mathrm{idle}} + (1 - e^{-\lambda_j T_j}) \times E_{\mathrm{active}}).$$

5. Performance analysis

- **Lemma 2**: The average energy consumption of the data transmission of an UE during an in-bound mobility of our proposed protocol is

$$P_{\mathrm{c_j}}(0, t_{\mathrm{dwell}_j}) = P_{\mathrm{c}_j} = e^{-(\hat{\lambda}_j t_{\mathrm{dwell}_j})}$$

$$E_{\mathrm{G}} = E + \frac{1}{n}\sum_{j=1}^{n}(e^{-\lambda_j T_j} \times E_{\mathrm{idle}} + (1 - e^{-\lambda_j T_j}) \times (e^{-\hat{\lambda}_j t_{\mathrm{dwell}_j}} \times E_{\mathrm{idle}} + (1 - e^{-\hat{\lambda}_j t_{\mathrm{dwell}_j}}) \times E_{\mathrm{active}}))$$

5. Performance analysis

- **Theorem 1:** Based on the results of lemma 1 and lemma 2, the average energy consumption of our proposed protocol is smaller than that of Ashraf protocol, $E_{\mathrm{G}} < E_{\mathrm{A}}$, i.e.,

$$E + \frac{1}{n}\sum_{j=1}^{n}(e^{-\lambda_j T_j} \times E_{\mathrm{idle}} + (1 - e^{-\lambda_j T_j}) \times (e^{-\hat{\lambda}_j t_{\mathrm{dwell}_j}} \times E_{\mathrm{idle}} + (1 - e^{-\hat{\lambda}_j t_{\mathrm{dwell}_j}}) \times E_{\mathrm{active}}))$$

$$<$$

$$E + \frac{1}{n}\sum_{j=1}^{n}(e^{-\lambda_j T_j} \times E_{\mathrm{idle}} + (1 - e^{-\lambda_j T_j}) \times E_{\mathrm{active}})$$

6. Simulation results

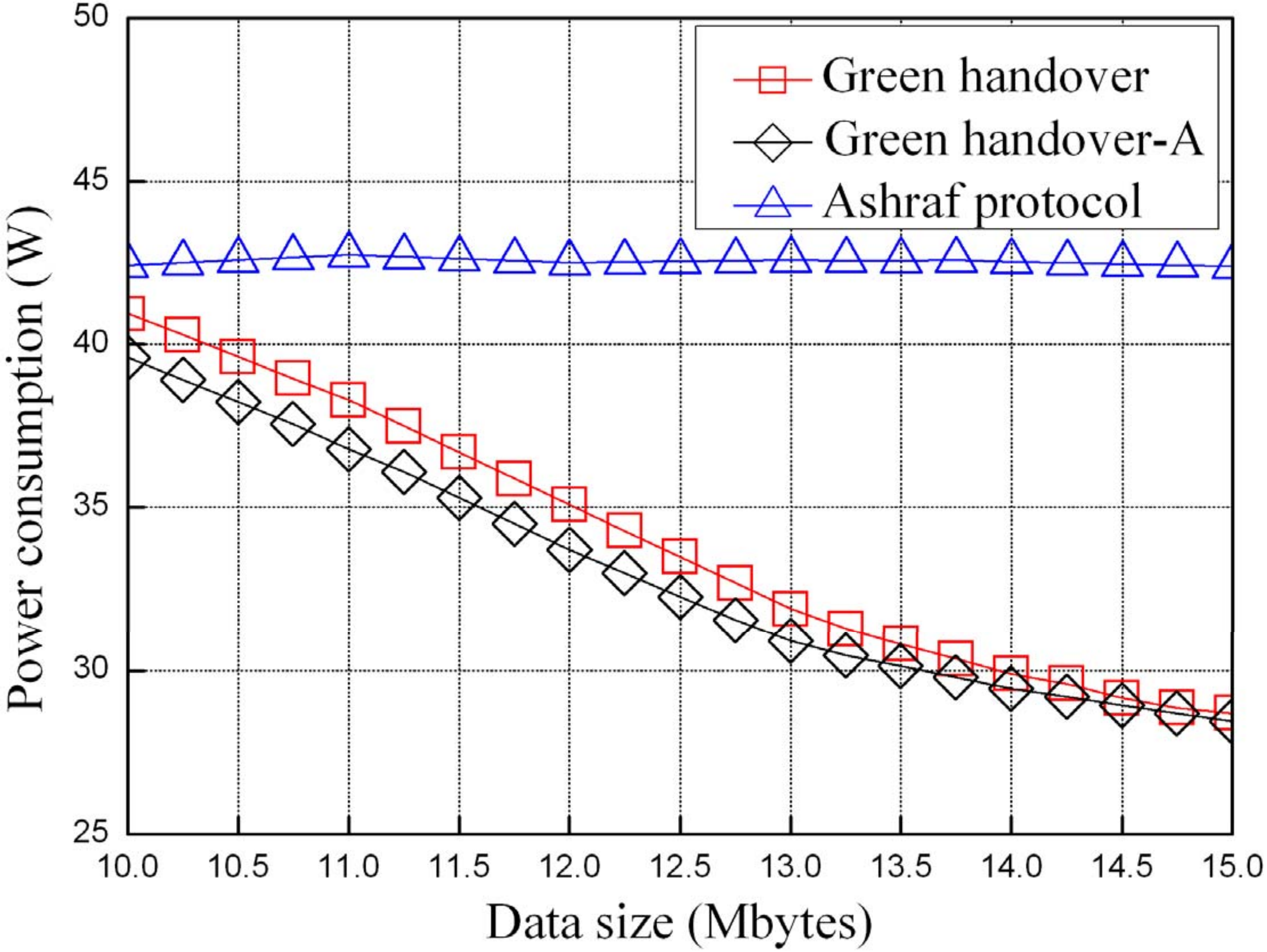
- Simulation tool:
  - NS-2 v2.28 + EURANE
- Simulation environment

Parameter	**Value**
Networks size	1000mX1000m
MBS transmission range	1000m
FBS transmission range	50m
Vehicle velocity	30 - 80 (km/hr)
Number of femtocells	6
Data size	10M - 15Mbytes
Packet size	1000bytes
Simulation time	20-40sec

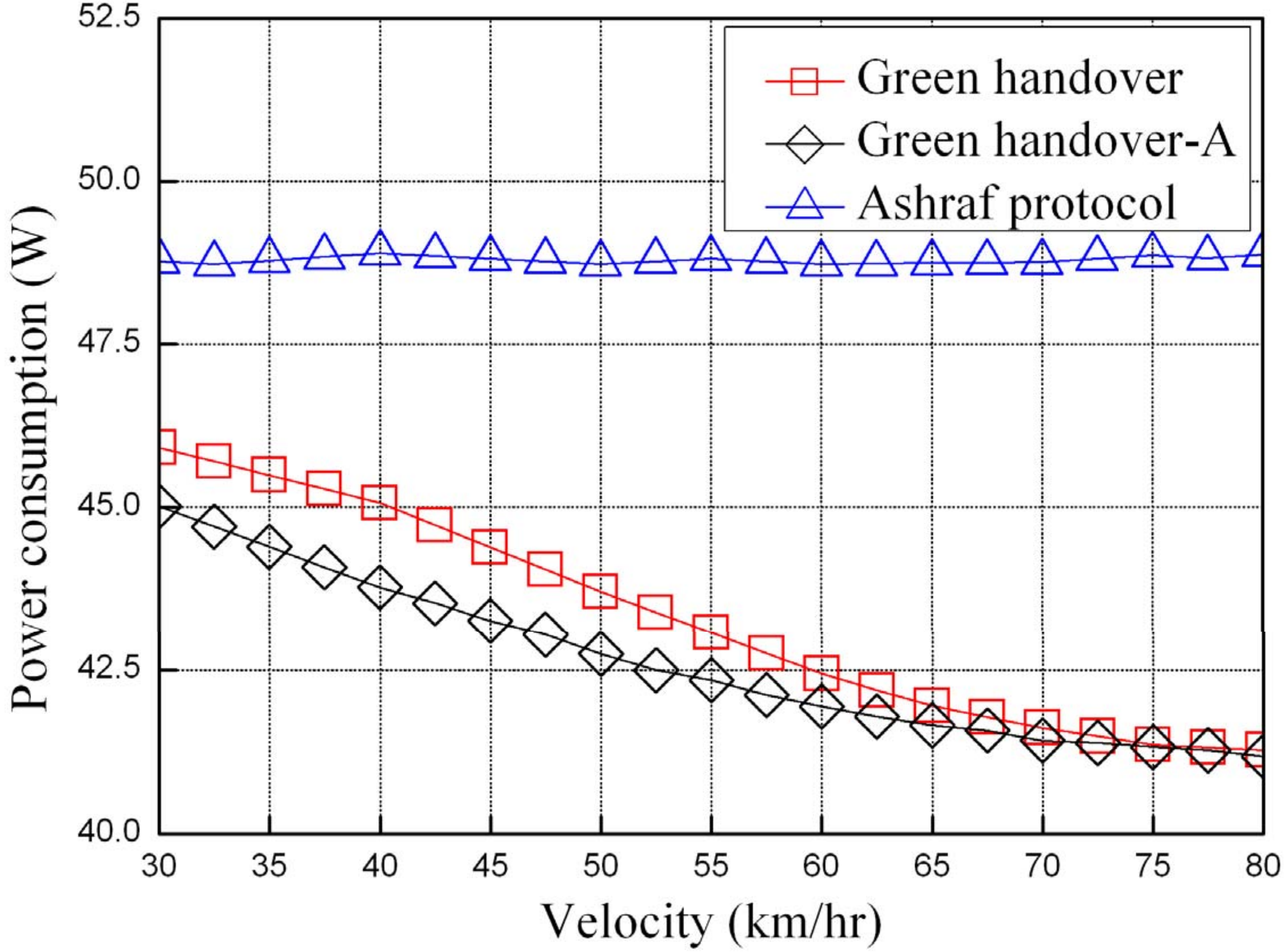
The performance metrics

- Power consumption of all FBSs
  - The total power consumption of an UE and all FBSs.
- Handover latency
  - The total time duration that the previous packet data is sent from serving BS to target BS.
- Packet loss
  - The packet loss occurs when one or more packets of data traveling across a network fail to reach their destination.
- Signaling cost of handover
  - The number of exchange information with MBS or FBS in the handover procedure.

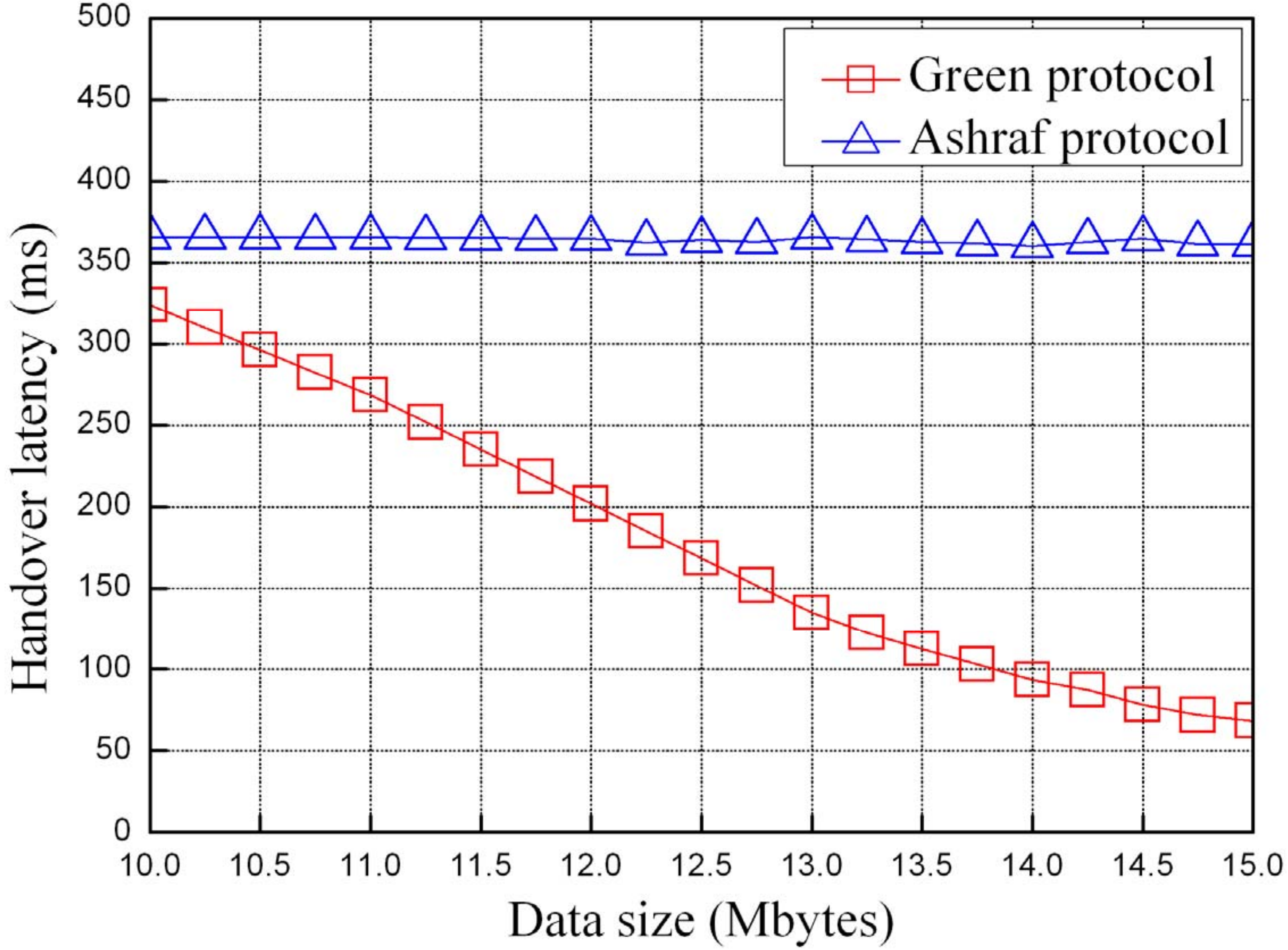
Power consumption vs. data size



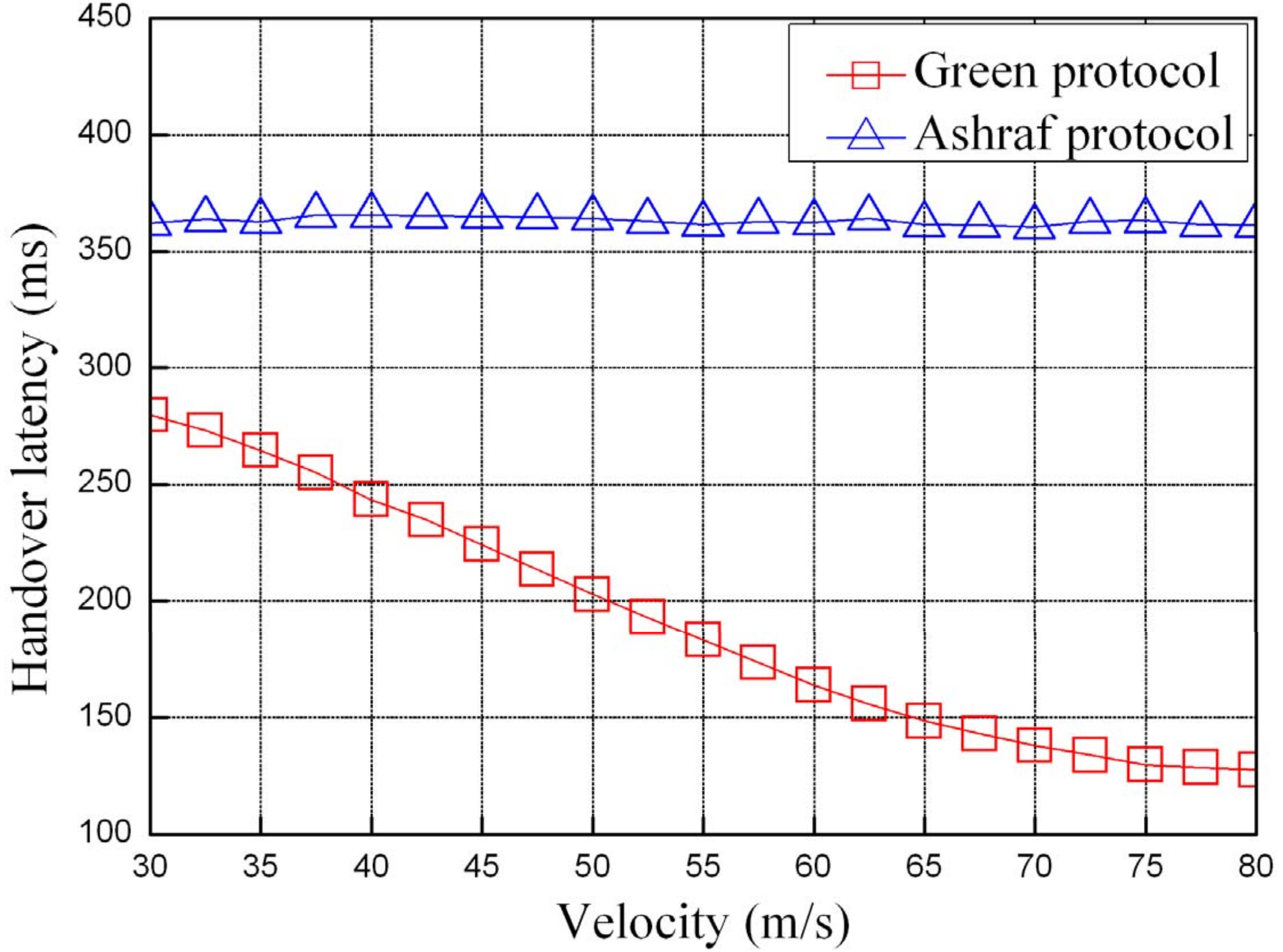
Power consumption vs. velocity



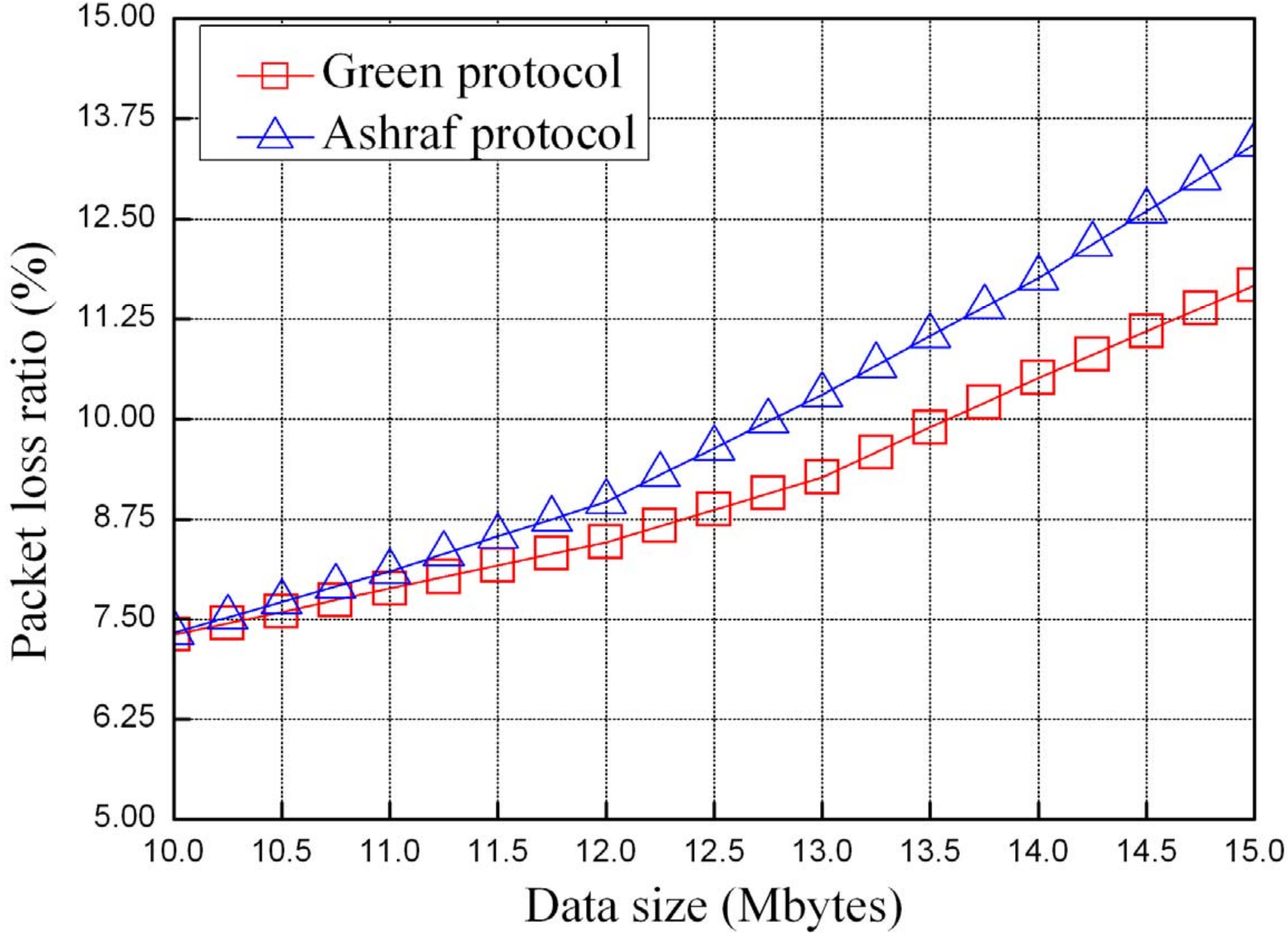
Handover latency vs. data size



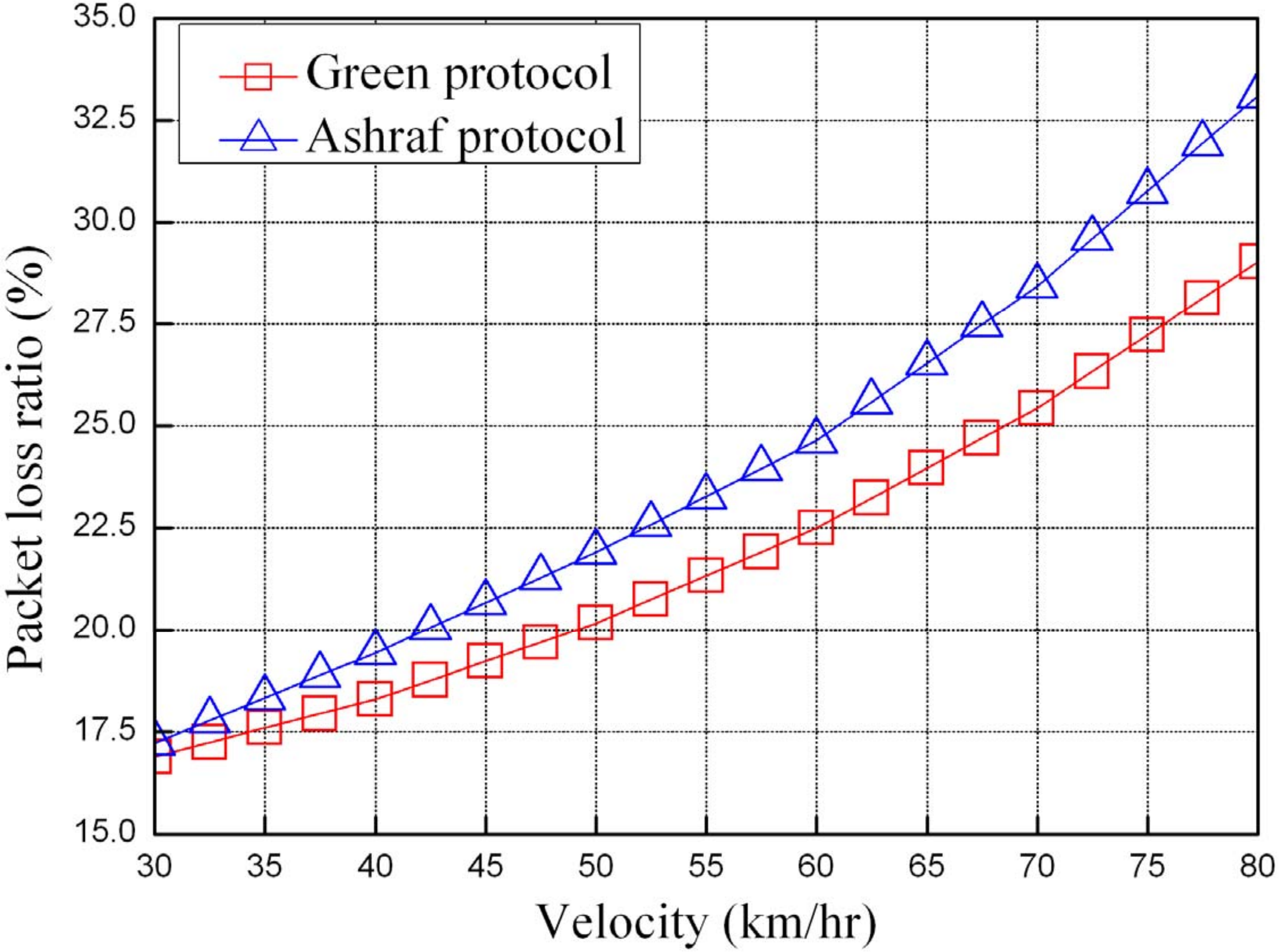
Handover latency vs. velocity



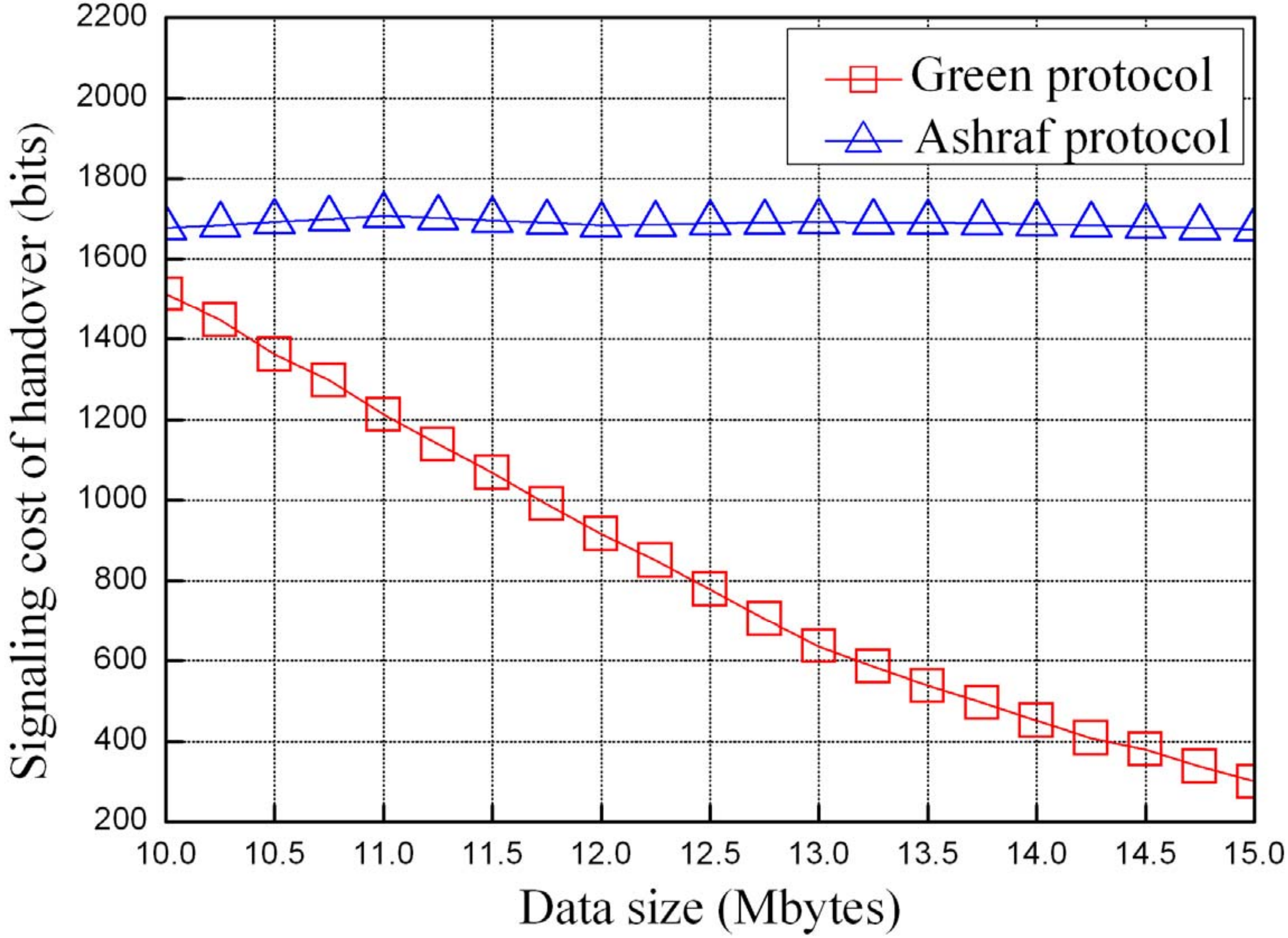
Packet loss ratio vs. data size



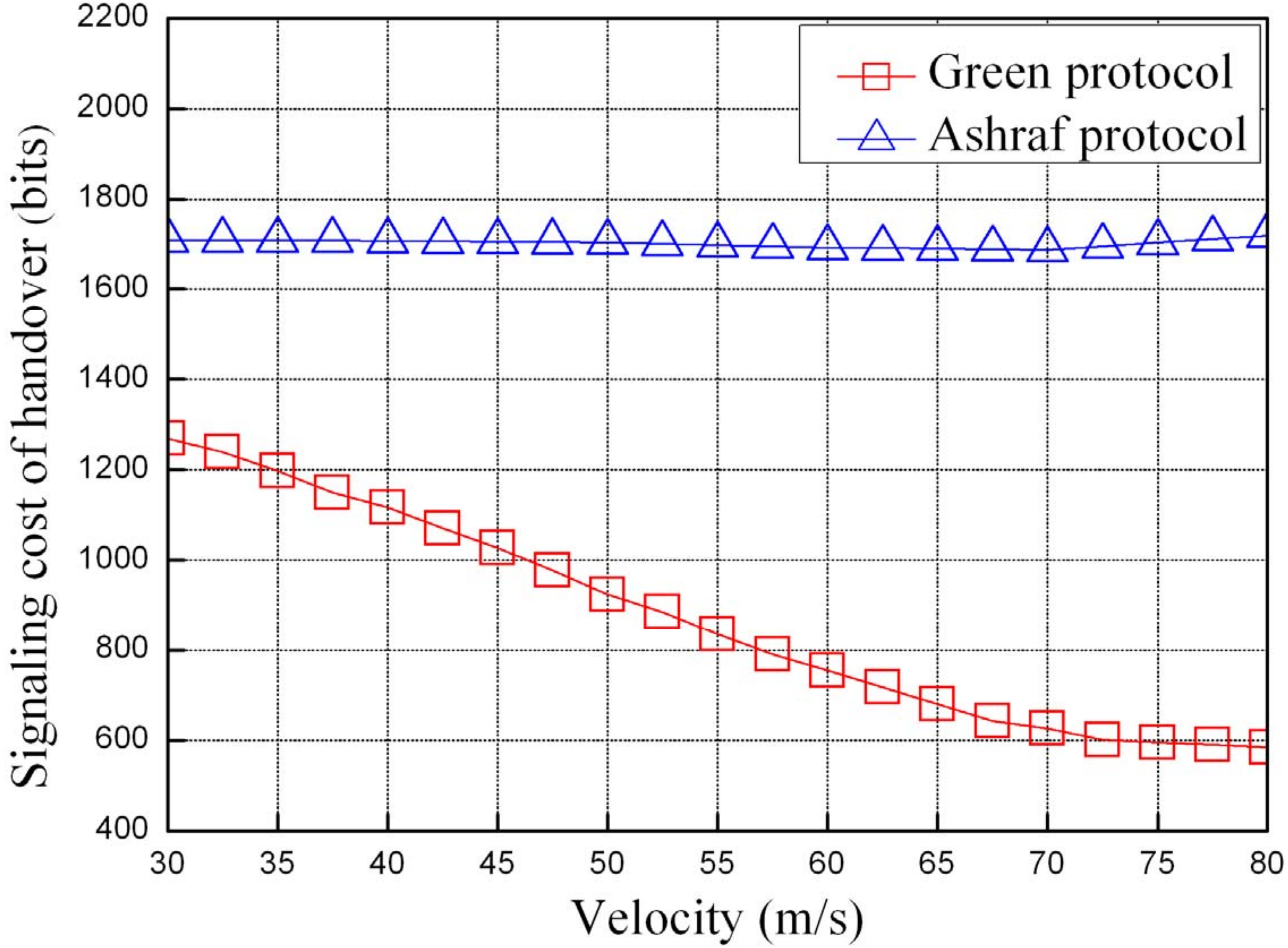
Packet loss ratio vs. velocity



Signaling cost of handover vs. data size



Signaling cost of handover vs. velocity



7. Conclusions

- This paper presents a green handover protocol in two-tier OFDMA macrocell-femtocell networks. With the consideration of the velocity and power consumption, a green handover protocol is developed in two tier cellular environment.

- The simulation results reflect that the proposed green handover protocol significantly reduce the power consumption and the number of undesired handovers.