FUJITSU

shaping tomorrow with you

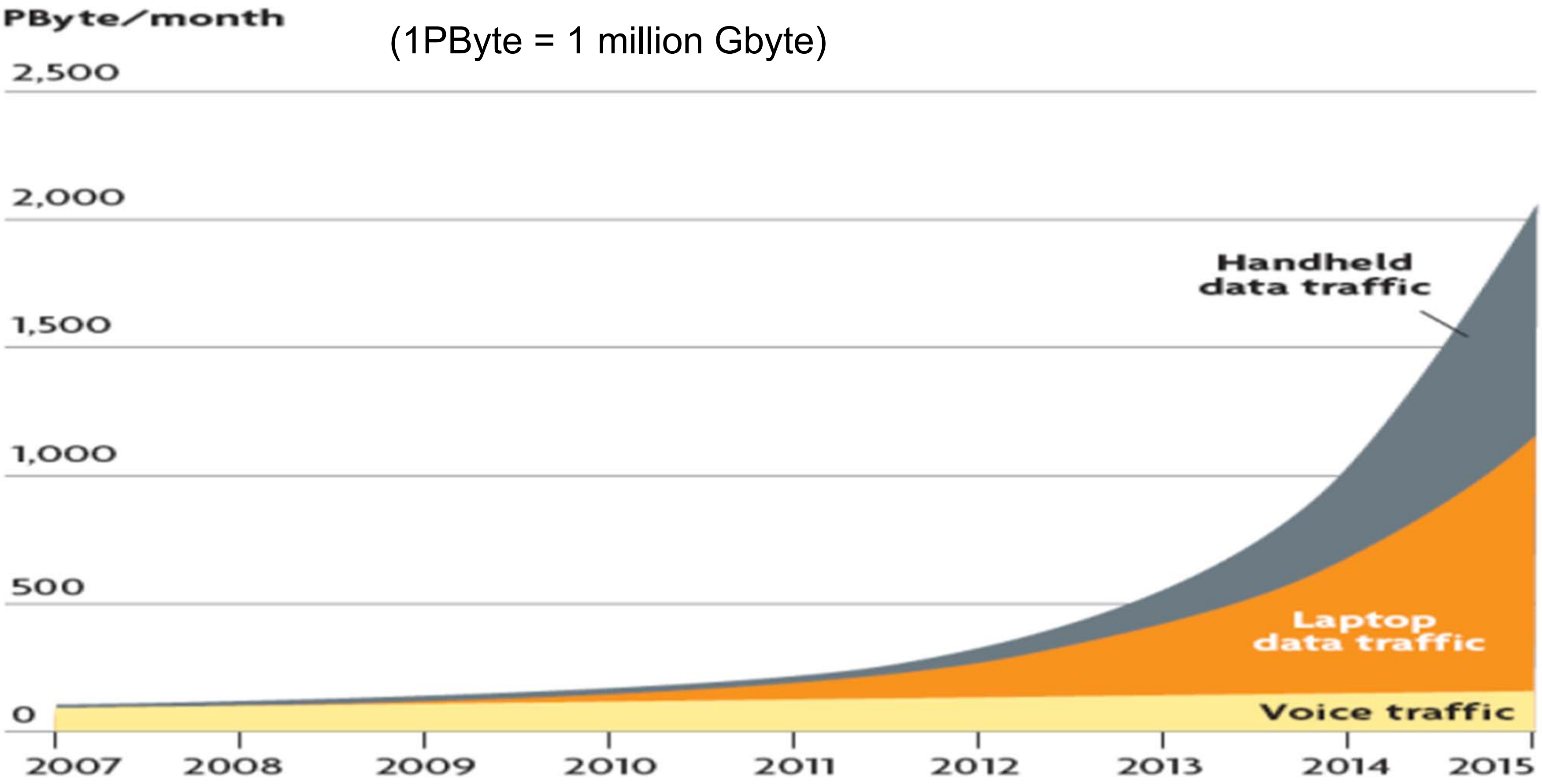
Adaptive Small Cell Access of Licensed and Unlicensed Bands

Ahmed Elsherif[*^], Wei-Peng Chen[*], Akira Ito[*], Zhi Ding[^]

[*] Fujitsu Laboratories of America, Inc.
[^] University of California, Davis

Issue: mobile data traffic growing exponentially

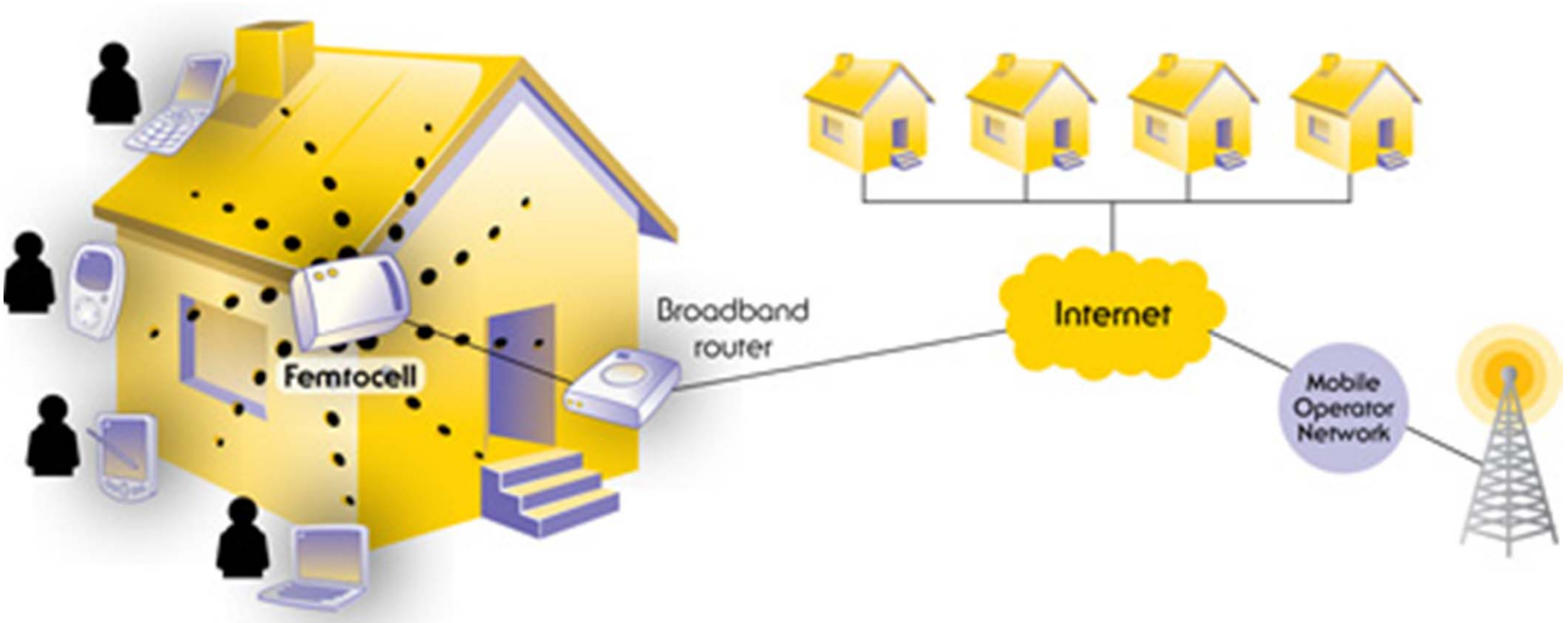
- New devices: smartphones, tablets and Netbooks.
- Proliferation of Mobile Internet Apps & Services.



Picture : recreated from an NSN presentation

Solution 1: small cells

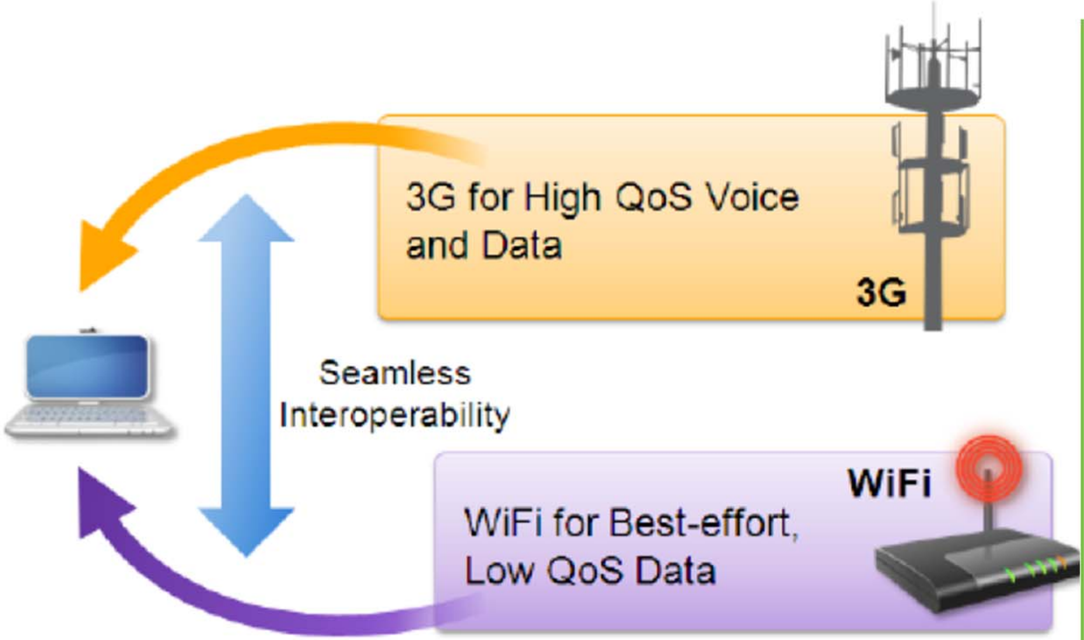
- Network densification increases system capacity
- By 2015, the investment from carriers in small cells will exceed traditional macrocell and microcells for both 3G and LTE



Source: http://www.smallcellforum.org/Files/Image/femtocell-house-diagram.jpg

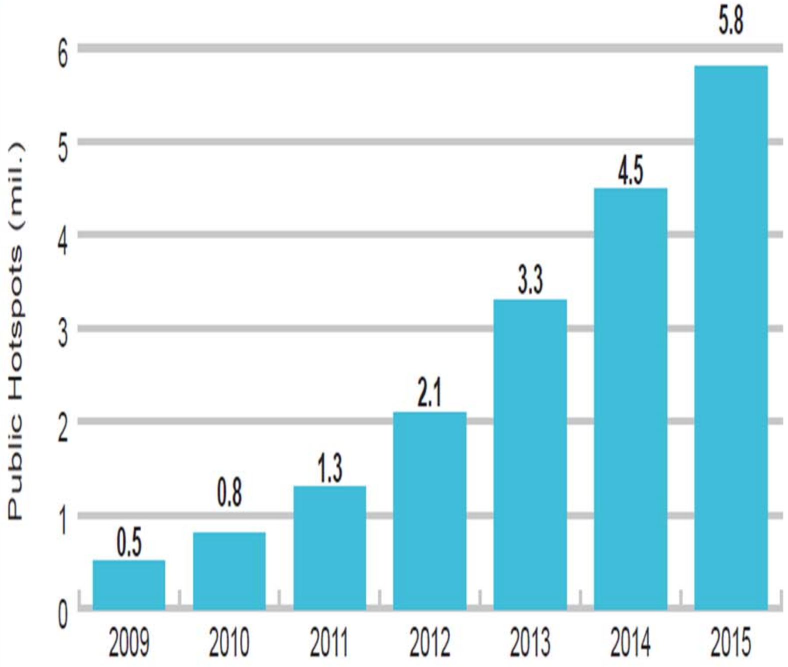
Solution 2: traffic offload to WiFi

- Ubiquity of WiFi interface at mobile devices
- Fast growing public WiFi hotspots



Source:Visiongain report: small cell reports 2011-2016

Global number of public WiFi hotspots

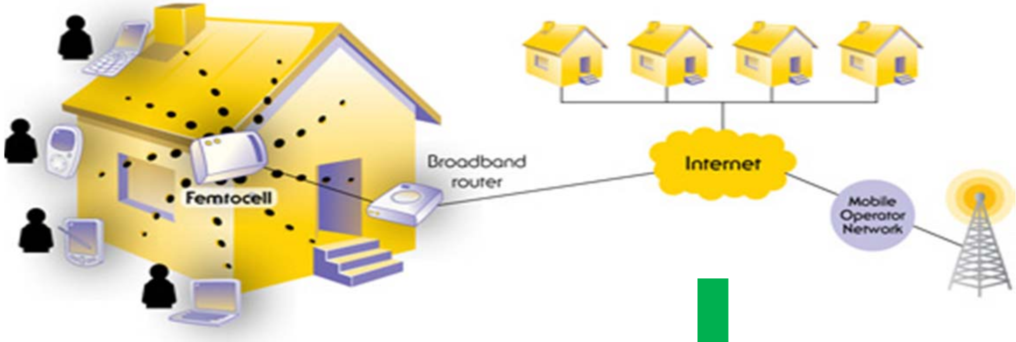


Source:
www.wballiance.com/component/files/dltrack.html?files=3b01001fba73a5422ad8e666052437b791a63974

Combined solutions: small cells with dual air interfaces

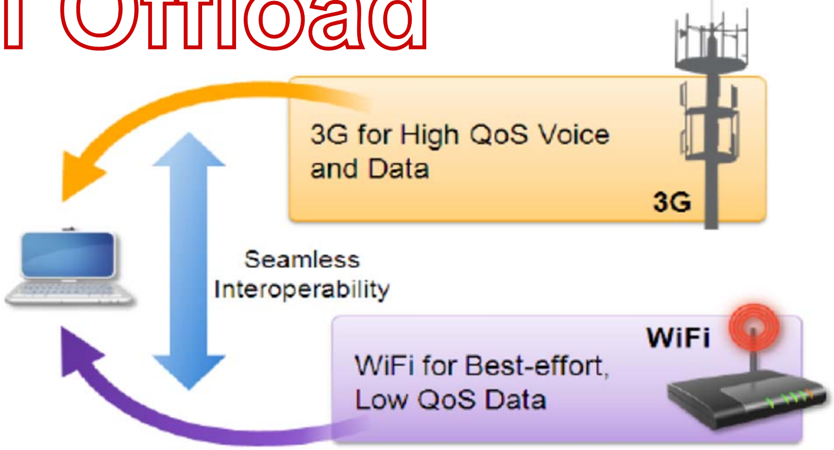
- Main market: to upgrade public WiFi hot spot with IFW (Integrated Femtocell and WiFi) networks

Small Cells



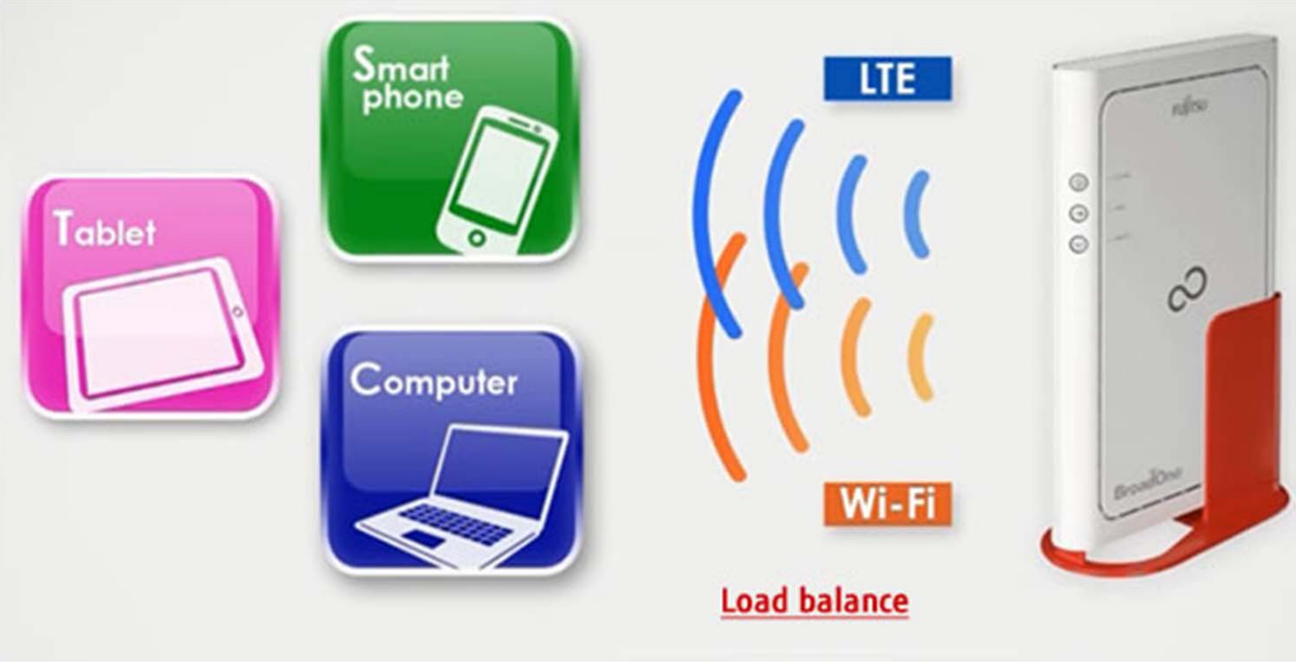
+

WiFi Offload



=

But wait! Do we really exploit the benefits of small cells with dual air interfaces?



One existing solution in mobile devices

- Data is transmitted over one interface at one air instance
- Change air interface would require manual reconfiguration
  - Of course seamless handover is not usually supported

When connected to WiFi, no data traffic is sent to cellular

Airplane Mode OFF

Wi-Fi CHM Public

Bluetooth Off

VPN OFF

Data is sent to cellular when WiFi is disabled or not any WiFi is selected

Airplane Mode OFF

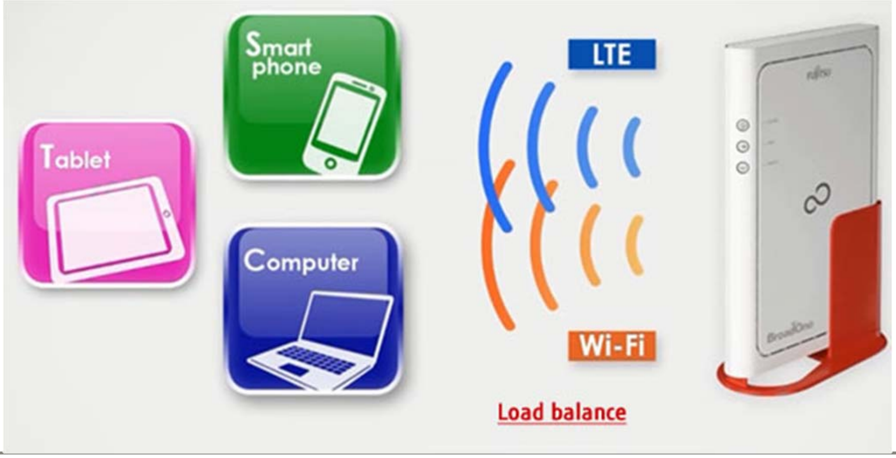
Wi-Fi Off

Bluetooth Off

VPN OFF

Basic idea of our proposal

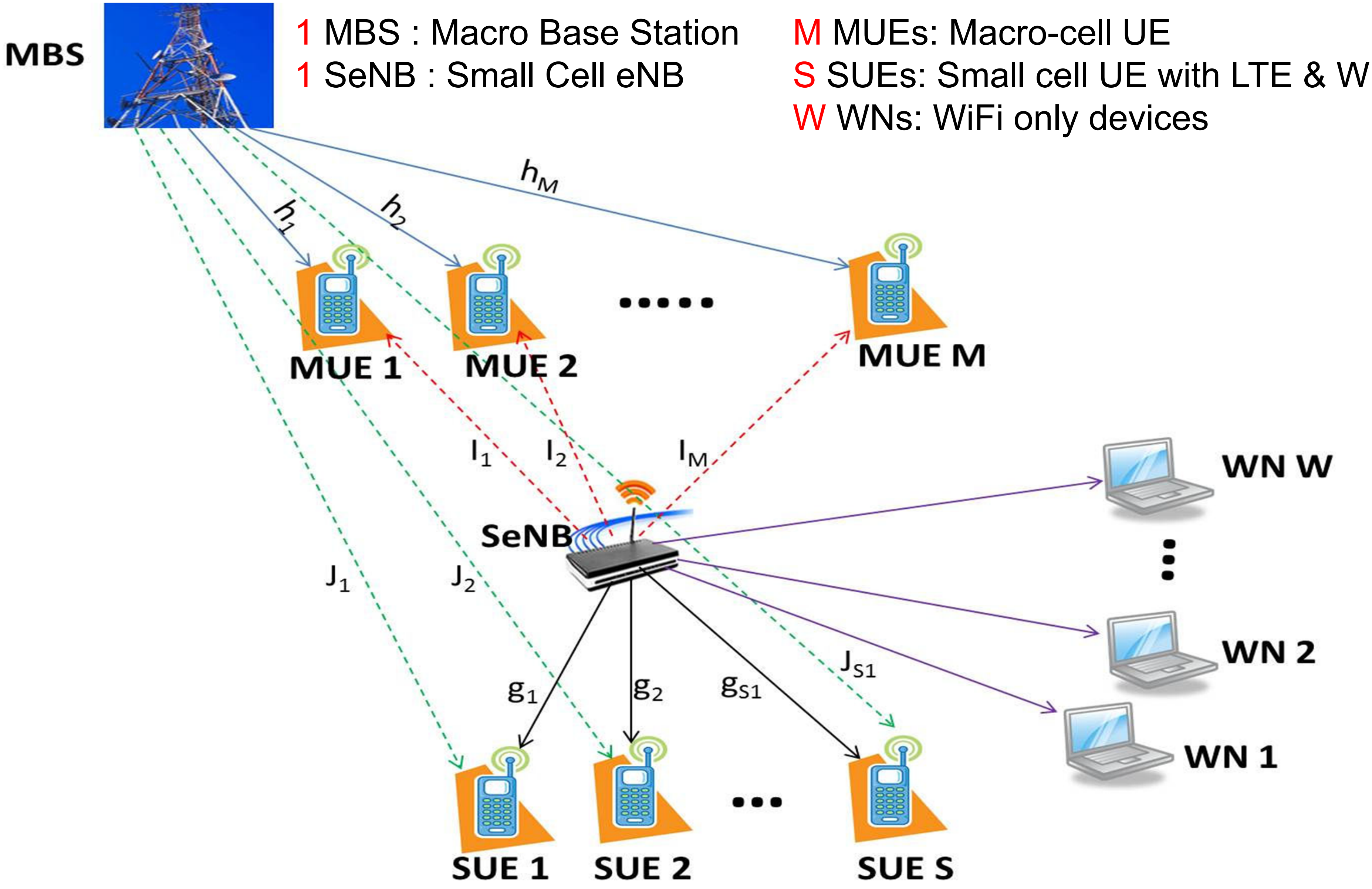
- Targeted system: small cells with dual LTE and WiFi interfaces
- Our unique solution: exploit the power of coordinating LTE & WiFi between eNB and UE
  - Aggregation and switching between LTE and WiFi for eNB and UE
    - Aggregation: higher data date can be supported when necessary
    - Switching: Load balance between two networks
  - Win-Win situation for both users and operators:
    - End users: better service quality
    - Operators: higher system capacity, and more revenue
  - Challenge: very different operations in LTE and WiFi



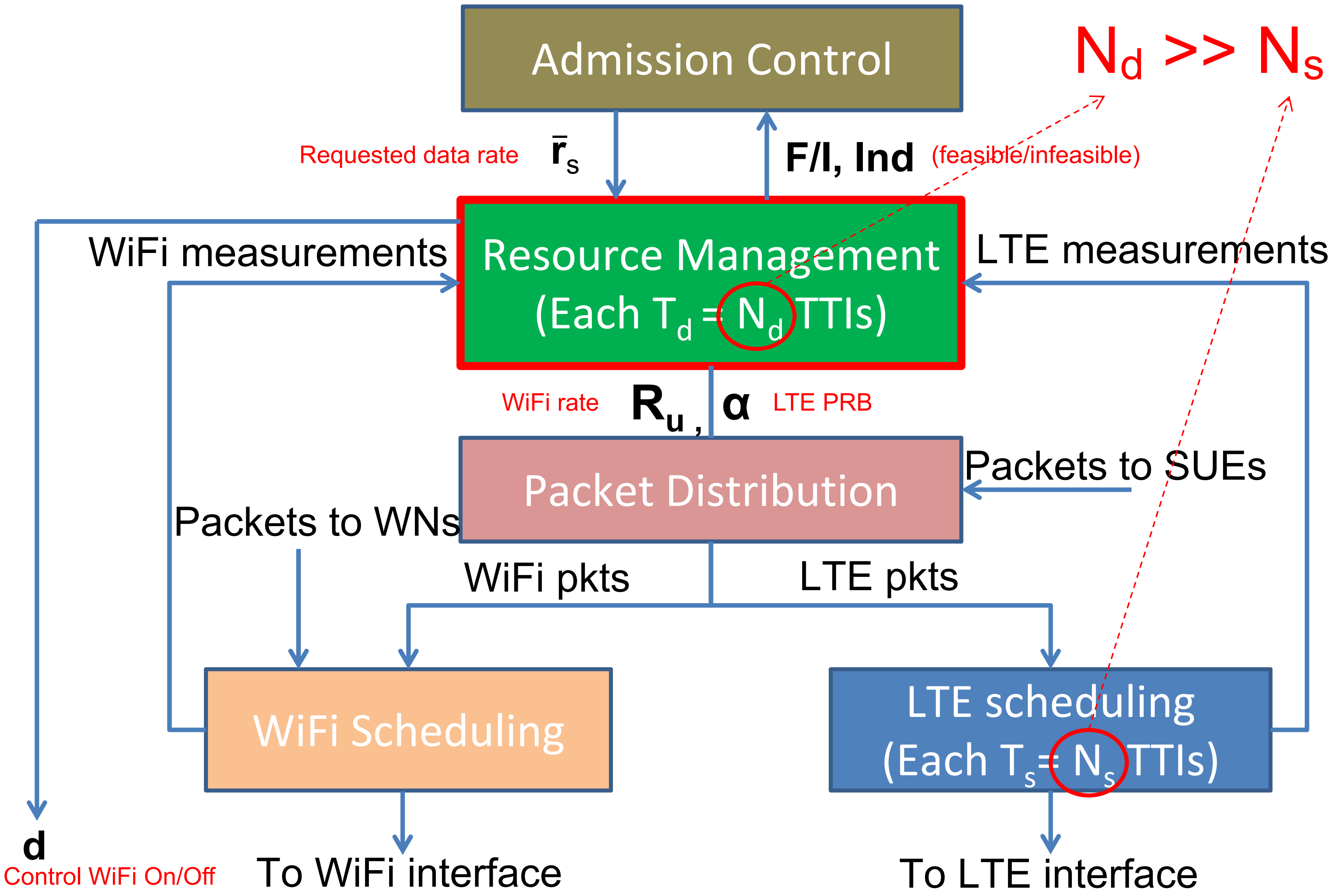
System model

1 MBS : Macro Base Station
1 SeNB : Small Cell eNB

M MUEs: Macro-cell UE
S SUEs: Small cell UE with LTE & WiFi
W WNs: WiFi only devices



System architecture



$N_d >> N_s$

Admission Control

Requested data rate $\bar{r}_s$

F/I, Ind (feasible/infeasible)

WiFi measurements

Resource Management (Each $T_d = N_d$ TTIs)

LTE measurements

WiFi rate R_u , α LTE PRB

Packet Distribution

Packets to SUEs

Packets to WNs

WiFi pkts

LTE pkts

WiFi Scheduling

LTE scheduling (Each $T_s = N_s$ TTIs)

d

Control WiFi On/Off

To WiFi interface

To LTE interface

Joint LTE and WiFi downlink radio resource management

- Goal: Jointly optimize resource allocation on both licensed and unlicensed band to have either switching between bands when one is congested or aggregation when higher data rate is requested.
- Objective function: Maximize sum throughput of SUEs (LTE + WiFi)
- Constraints :
  - LTE inter-cell interference: satisfy MUEs minimum rate
  - Satisfy SUEs minimum rate ($R_{LTE} + R_{WiFi} \geq R_{min}$).
  - Minimum rates for WNs are guaranteed
  - Sum of WiFi throughputs to SUEs and WNs ≤ SeNB's WiFi capacity
- Idea:
  - Model WiFi capacity based on CSMA/CA operation ⇒ WiFi capacity is a function of the number of contending stations
  - Optimization problem can be simplified as linear programming problem

Joint downlink radio resource management

$$\underset{\{\boldsymbol{\alpha},\boldsymbol{R_u}\}}{\text{maximize}} \quad \sum_{i=1}^{S}\Big[\overbrace{\psi_\ell^{(i)}B_d\alpha^{(i)}}^{\text{LTE rate of SUEs}} + \overset{\substack{\text{WiFi rate of SUEs}\\ \downarrow}}{R_u^{(i)}}\Big],$$

LTE PRB

$$\text{subject to} \quad \sum_{i=1}^{S} R_u^{(i)} \le \boxed{R_{\mathrm{AP}} - \sum_{k=1}^{W} R_w^{(k)}},$$

Extra WiFi capacity

$$\psi_\ell^{(i)}B_d\alpha^{(i)} + R_u^{(i)} \ge \bar{r}_s^{(i)}, \; i = 1,\ldots,S,$$

Min. rate requirement of SUE *i*

Rate of MUE *j*

$$R_m^{(j)} \ge \bar{r}_m^{(j)}, \; j = 1,\ldots,M,$$

Min. rate requirement of MUE *j*

$$\sum_{i=1}^{S} \alpha^{(i)} \le \bar{\alpha} - \beta = \bar{\alpha}_s,$$

$$0 \le \alpha^{(i)} \le 1, \; i = 1,\ldots,S,$$

$$R_u^{(i)} \ge 0, \; i = 1,\ldots,S.$$

Simulation comparison

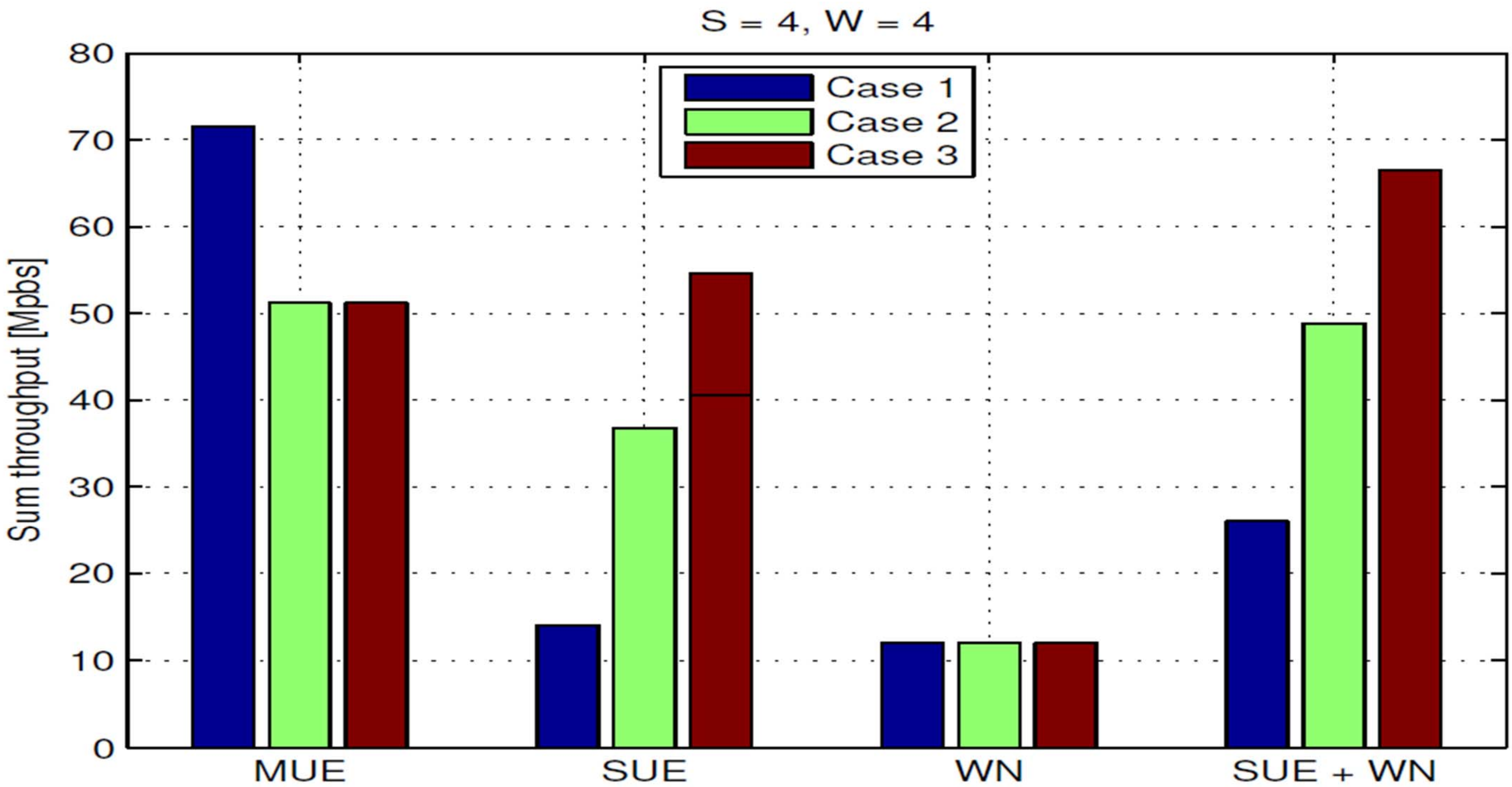
- Case 1 : WiFi hotspot
  - MBS uses the whole licensed band to serve MUEs, while WiFi hotspot serves both SUEs and WNs.
- Case 2 : Femto (independent WiFi & LTE operation)
  - MBS and SeNB share licensed band
  - SeNB uses LTE to serve SUEs and uses WiFi to serve WNs
- Case 3 : Proposal (coordinated WiFi & LTE)
  - MBS and SeNB share licensed band
  - SeNB uses LTE and WiFi to serve SUEs and uses WiFi to serve WNs

- MBS: Macro-cell base station
- SeNB: small-cell eNB

- MUE: Macro-cell UE connected to MBS
- SUE: UE with both LTE & WiFi (e.g. smartphone)
- WN: Wireless node with WiFi only (e.g. laptop)

Simulation results

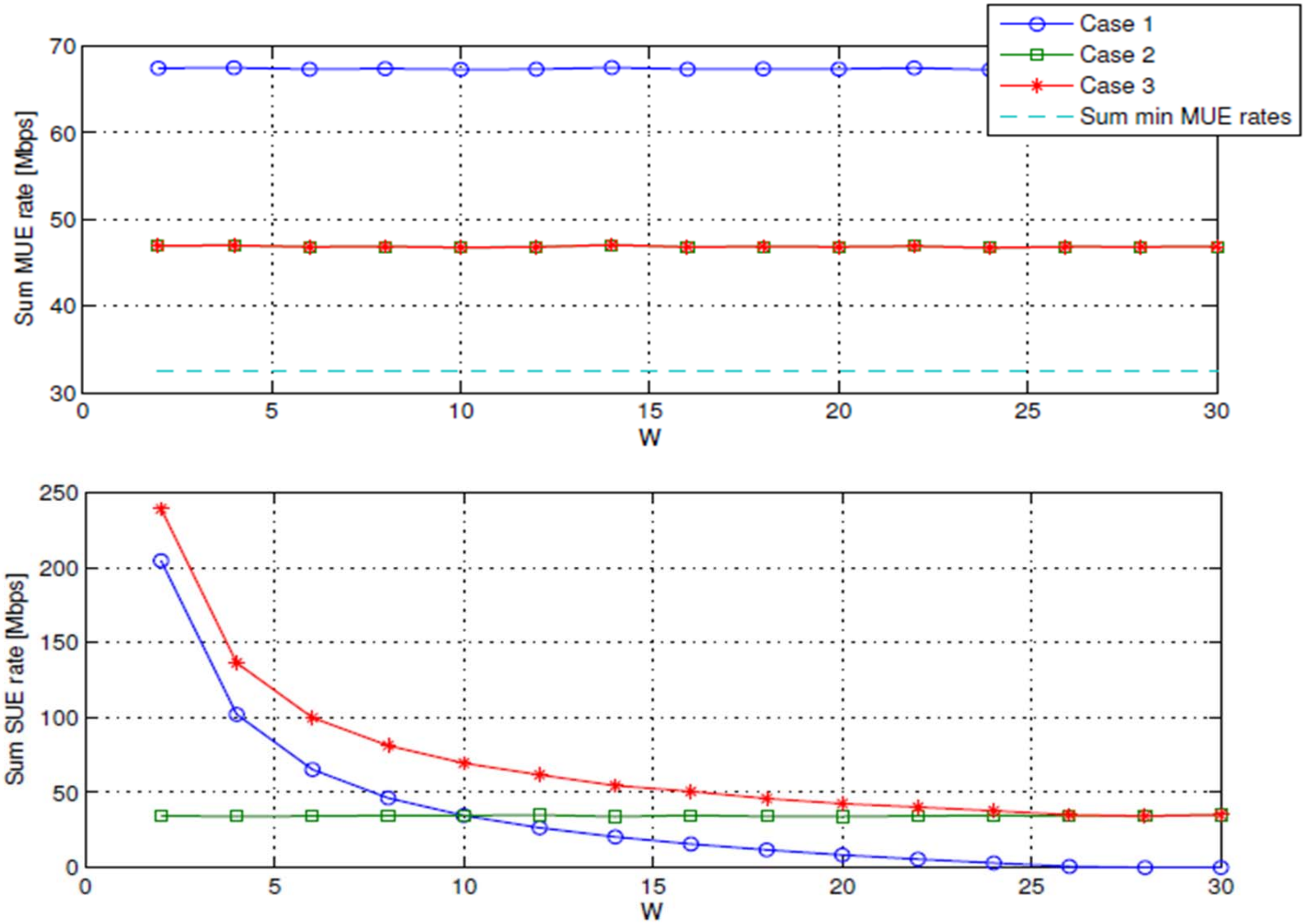
- The proposed solution gives the largest sum SUE + WN throughput



- SUE: UE with both LTE & WiFi (e.g. smartphone),
- WN: Wireless node with WiFi only (e.g. laptop)

Simulation results

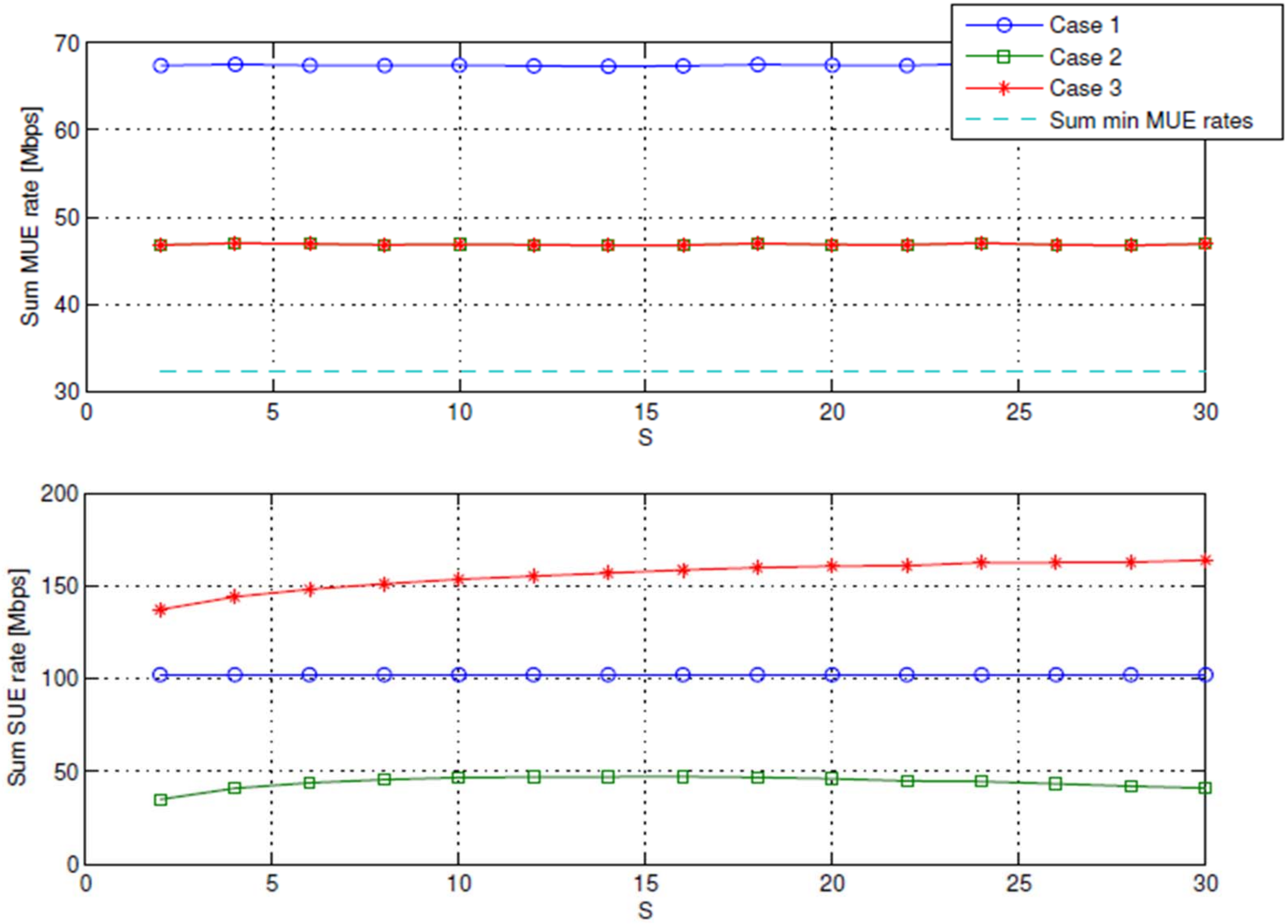
- Sum throughput vs **W** (Number of WNs), S = 2



As W increases, contention on WiFi increases ➔ Less WiFi capacity ➔ Lower sum SUE rate

Simulation results

- Sum throughput vs **S** (Number of SUEs), W = 2



As S increases, sum SUE throughput increases till it is hard to meet the SUE requirements (no enough resources)

Conclusion

- Propose a joint resource allocation strategy to offload traffic or enhance per-user throughout via dynamic switching and/or aggregating LTE and WiFi air interfaces, respectively.

- Better performance than existing solutions (Conventional Femtocells and WiFi hotspots) due to jointly utilizing both LTE and WiFi bands.

- Low-complexity solution (a linear programming problem that can be solved efficiently in a polynomial time).

FUJITSU

shaping tomorrow with you