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Design of Green Smart Room Using Fifth Generation Network Device Femtolet

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Abstract

Designing smart room with energy-efficient data and application offloading facilities for the users is a crucial issue. This paper has proposed the architecture of a self-organized smart room where the users can offload their data and applications at low power and low latency. Sensors and detectors are used to collect status of the objects present in the room and according to the collected information, the microcontroller operates other devices e.g. lights, AC, smoke detector etc. located inside the room in order to create a self-organized environment. In the proposed architecture fifth generation network device Femtolet is used as a small home base station with cloud environment. The proposed smart room architecture is implemented using network simulator Qualnet version 7 and its performance is evaluated with respect to energy consumption, carried load, delay, jitter and throughput. The simulation results show that Femtolet reduces the energy consumption and delay in accessing cloud services by approximately 14–57% and 8–35% respectively than the femtocell base station to build a green smart home environment.

Keywords Femtolet · Smart room · Power · Sensors · Microcontroller

1 Introduction

A self-organized system has autonomous functionalities [1, 2]. Such a system integrates the optimization, planning and configuration processes. A smart environment acts as an intelligent agent and monitors its surrounding through the use of physical components such as sensors, smart devices and controllers [3]. It gathers information and makes

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it available to the system database. This information is used for making decisions and selecting actions to be executed by the agent through the use of a controller that has an effect on the environmental state. Based on the information the system reacts. Thus the system is called a self-organized system where behaviour of the system depends on the surroundings. This self-organized system is used to create a smart environment.

The ever increasing user demand for unlimited capacity and high speed data services has made the mobile communication technology more complex, heterogeneous as well as expensive. As most of the requests are generated by the indoor users, good quality of service (QoS) and quality of experience (QoE) are required at indoor region. To increase the signal strength at indoor region, femtocells are allocated in the residential and official buildings present inside the coverage of a macrocell base station [4–6]. Femtocell which is popular as home node base station (HNB) is a low cost plug and play device that has low transmission power and can be deployed by the user himself/herself [7, 8]. The femtocell switches on or off automatically based on the existence of active mobile devices under its coverage, it is called self-organized femtocell [1, 2]. Though femtocell gives high signal strength, high speed internet access is still a promising issue. To fulfil this objective, in our previous work [9] we have introduced fifth generation (5G) network device Femtolet exclusively for low power and high speed mobile-cloud network. In [9] we have shown how Femtolet reduces the power and latency consumption than the existing femtocell based mobile cloud network. Figure 1 shows the architecture of Femtolet with its working principle [9].

Femtolet contains all the components of femtocell like radio frequency receiver (RFR), radio frequency transmitter (RFT), microprocessor, field programmable gate array, power amplifier as well as all the elements like storage, memory which are required to provide cloud services i.e. infrastructure as a service, platform as a service and software as a service. Mobile devices registered under a Femtolet are able to offload computation and data both inside the Femtolet.

In this paper we have proposed a self-organized smart room scenario where Femtolet is used. The organization of this paper is: Sect. 2 presents the related works, Sect. 3 presents the architecture of the proposed smart room environment along with its working principle, the simulation model is given in Sect. 4, the proposed work is compared with existing works in Sect. 5, and finally we conclude in Sect. 6.

1.1 Motivation and Contributions of Proposed Work

Self-organized smart room creation is a major challenge today. Existing smart room technology uses femtocell or cloudlet [10, 11] or Small Cell cloud-enhanced e-node B (SCceNB) [12–14] for high speed internet access or to improve the signal quality. Using only cloudlet user can only get high speed internet access but they are unable to get voice call facility. Femtocellor cloudlet gives single type of facility, either very good internet access or very good signal level to avoid call dropping due to poor signal quality. Although SCceNB has partially overcomes this problem, it is observed that Femtolet which is a combination of femtocell and cloudlet, offers high speed cloud access and high signal strength at the same time with lower power consumption than femtocell plus cloudlet and SCceNB [9]. Our motivation is:

- To propose a novel architecture of self-organized smart room that will not only operate the devices as per user's existence in the room but also provide good quality of service to the user in terms of delay and energy consumption during internet access.

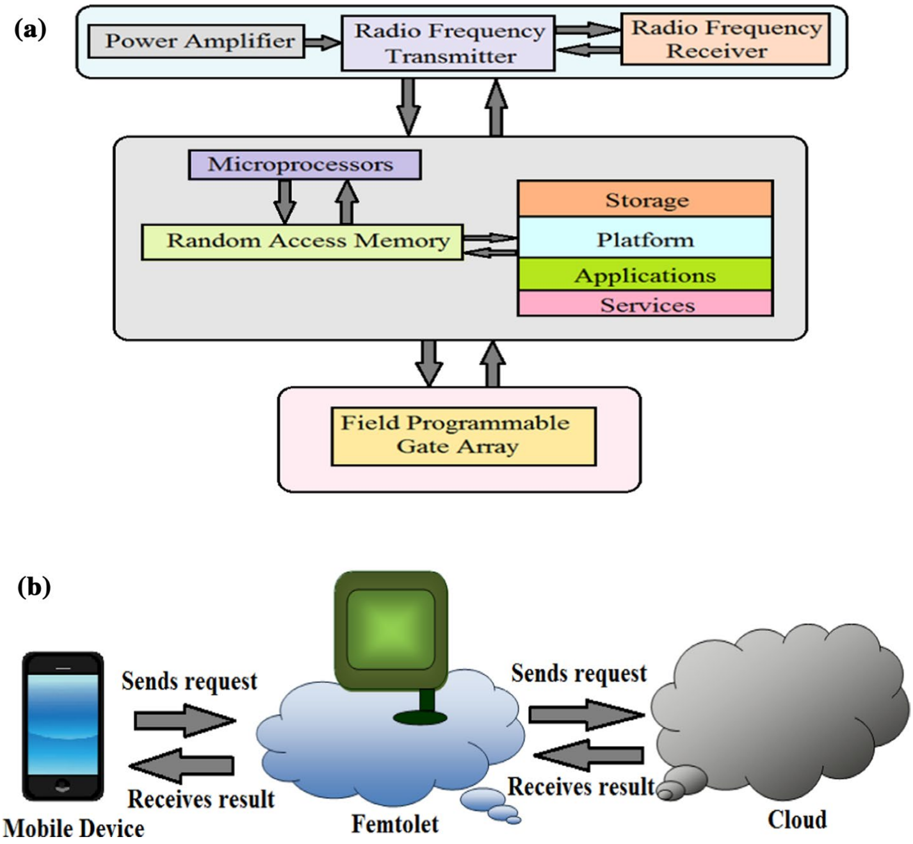

Fig. 1 Architecture of Femtolet with its working principle [9]. **a** Architecture of Femtolet, **b** Working model of Femtolet

For this purpose, the contributions of this paper are:

1. The architecture of a self-organized smart room environment is proposed. Sensors are used in the room in such a way that it can keep track of the number of entry and exit of active mobile terminal (MT) in the room. Depending on the information, the devices located in the room are turned on/off automatically in a self-organized way. Use of 5G network device Femtolet in the proposed architecture reduces energy consumption and delay in cloud access than the existing femtocell base station. As Femtolet plays a vital role in reducing energy consumption and delay in the proposed architecture, the proposed smart room environment is called as ‘Femtolet Based Self-Organized Smart Room Environment’ (FBSOSRE).
2. Use of Femtolet provides the users to access the cloud services through Femtolet because the Femtolet possesses storage and computation abilities. This feature makes the proposed approach exclusively novel with respect to the existing smart home system where the users have to access the remote cloud server if they want to offload code or applications. Access to remote cloud server increases delay and energy consumption.

Use of Femtolet solves this problem because the distance between the Femtolet and the requesting device is very small as the coverage of a Femtolet is 10–20 m approximately.

3. The proposed FBSOSRE is implemented using network simulator Qualnetversion 7 (Qualnet7). The simulated model can detect the presence of active MTs in the room and depending on the user behavior it switches on/off the devices to develop an automated self-organized environment.
4. The performance analysis of the proposed FBSOSRE is carried out with respect to delay, jitter, carried load, throughput and energy consumption. It is demonstrated by the simulation results how Femtolet reduces the energy consumption to create a green smart room environment.

2 Related Works

Next generation mobile communications have already brought to light several challenging and exciting applications which promise to change the way of communication and interaction among people. Smart room technology is one of those exciting and challenging applications. Smart room technology involves human action identification, object tracking, behaviour sensing, activity detection etc. In [15] a multidimensional approach has been designed to create a smart room for identifying, estimating and tracking the location of a participant. Using multidimensional approach, an improved performance can be achieved for spatial localization, speech detection of participants and identification. The daily living activities are recognized in [16]. For activity modelling, ontological and temporal activities are integrated in [17]. Hazards analysis in smart home environment is carried out in [18, 19] using emotive computing framework. To efficiently utilize the resources a data mining approach is used in [19]. Wireless sensor network [20–22] plays an important role in the smart room creation. Sensor nodes are attached with the room equipments such as door, bath tub etc. In [23] a home monitoring system has been designed and implemented using wireless sensor network. In our approach the combination of femtocell and cloudlet i.e. Femtolet is used to offer high speed cloud access and high signal strength at the same time with lower power consumption for creating a smart room environment.

Mobile cloud computing (MCC) offers mobile devices platform for storing data and executing applications to decrease the power consumption [24–26]. MCC integrates mobile computing with cloud computing [27, 28]. But remote cloud access by a mobile device increases the delay. Consequently the QoS degrades along with the QoE. To reduce the delay, cloudlet comes into the scenario [10, 11]. To improve the security and offer good signal level at indoor area during cloud access, femto-cloud network has come. Accessing cloud services through a femtocell base station is referred as femto-cloud network [29, 30]. Femto-cloud network improves the security through the use of security gateway [29, 30]. Femto-cloud network can be of four types: (1) femtocell is connected with cloud [29–33], (2) femtocell is connected with cloudlet [10, 11] that includes cache copies of data and code of cloud for offloading purpose [9], (3) SCceNB [12–14], and (4) Femtolet. Nowadays self-organized femtocell [1, 2] is deployed in smart room environment [34–37] for operating based on user's presence in the room. Activating femtocell according to user's existence reduces its energy consumption [35]. The use of femtocell to improve signal strength inside home is demonstrated in [38, 39]. The use of 5G technology in the wireless sensor network based smart home is discussed in [40]. In [9], Femtolet is proposed as a 5G network [41, 42] device.

3 Femtolet Based Self-Organized Smart Room Environment

3.1 Architecture of FBSOSRE

In the proposed work a single room is considered with an attached washroom in a three bedroom home. It is considered that the room can be covered by a single Femtolet having a coverage area of 10–20 m. The architecture of the smart room is pictorially presented in Fig. 2.

The room consists of the following components: (a) Door with Rotation Sensor (R), (b) Pass Card Detector (PCD), (c) Mobile Terminal Detector (MTD), (d) Femtolet (F), (e) Sensor Data Receiving Node i.e. Sensor Base Station (SB), (f) Lights (L1, L2, L3), (g) Alarm (A), (h) Smoke Detector (SMD), (i) Air-Conditioning Machine (AC), (j) Indicator (I), (k) Microcontroller. The washroom contains: (a) Passive Infrared Occupancy Sensor (POS), (b) Light (L4).

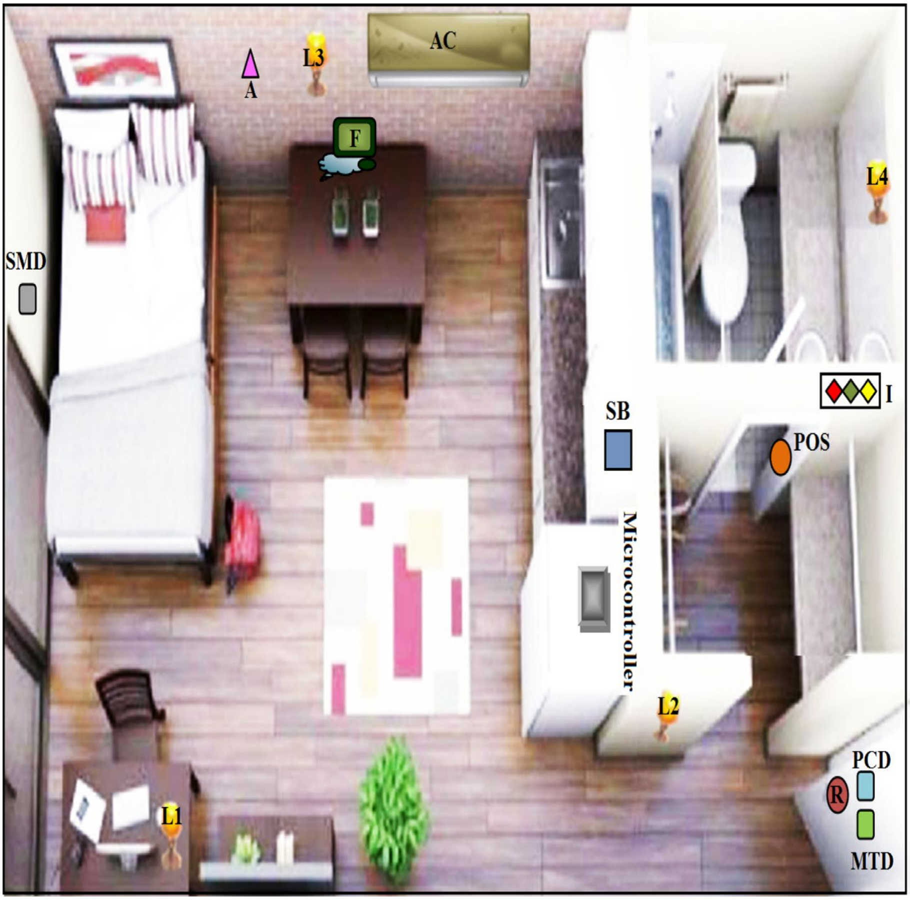

Fig. 2 Architecture of smart room with an attached washroom

3.2 Devices Used in FBSOSRE

The interconnection between the devices used to design FBSOSRE is shown in Fig. 3. It is observed that the sensors and detectors send input to the microcontroller and based on the received input, the microcontroller sends output to other devices like Femtolet, lights, AC, indicator and alarm.

The devices of FBSOSRE are discussed as follows.

A. Microcontroller: In the microcontroller the application programs run. According to the inbuilt logic, the application program receives digital input and sends output to the parallel port through pins. It stores the required information in a text file 'record.txt'. Parallel port sends the output pulse to the control card. Control card is a custom made circuit with which the sensor base station i.e. sensor data receiving node (SB), Femtolet (F), lights (L1, L2, L3 and L4), AC machine, indicator and alarm are connected. The connection of the devices with the microcontroller is shown in Fig. 3. SB is connected with all the sensors and detectors (R, PCD, MTD, SMD and POS). After receiving sensor data, SB informs the microcontroller which therefore controls other devices in the room. A timer is connected with the system to track the automated operations. This timer triggers an alarm when a preset threshold limit is crossed.

B. Sensor Base Station: The sensor base station is used to receive the sensor data from the sensors and detectors present inside the room (R, PCD, MTD, SMD and POS). After receiving the data, SB forwards the data to the microcontroller as shown in Fig. 3.

C. Door with Rotation Sensor: The rotation sensor R [43, 44] is placed at the door. A rotating door is used in the system. This door may rotate in both directions: clockwise and anti-clockwise. Only one side of the door is open for entry and exit purposes. In the proposed scenario it is assumed that all the doors of the room open in clock wise direction and close in anti-clockwise direction. When a person enters into the room, the door rotates in clockwise direction. During exit time the door rotates in anti-clockwise direction. This sensor detects whether the door is rotating clockwise or anti-clockwise to check the entry and exit of user in the room. R is connected to the microcontroller

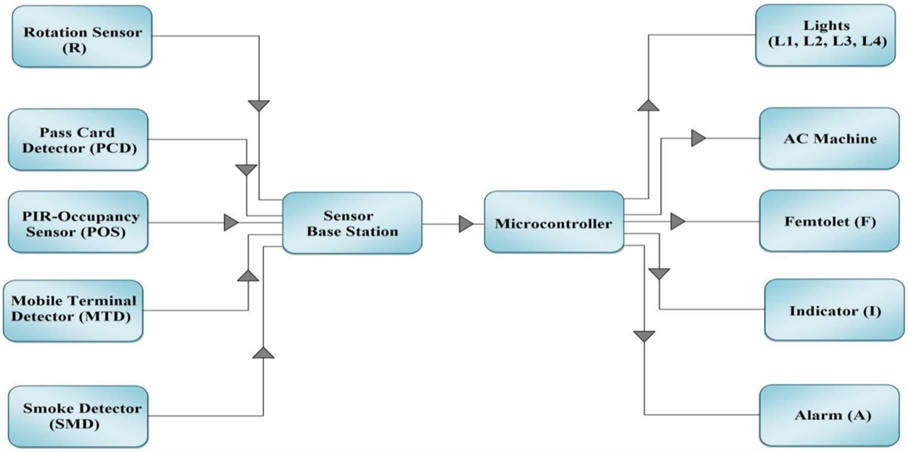

Fig. 3 Interconnection of devices used in FBSOSRE (Lights not light)

through SB as shown in Fig. 3. When a user enters or exists from the room, R sends this information to the microcontroller via SB.

D. Pass Card Detector: A Pass Card Detector i.e. PCD is a magnetic card which permits a user to enter into the room. PCD is placed at one side of the door. When a user wants to enter into or exit from the room, he/she inserts his/her pass card in PCD. Then the door is unlocked or locked. After entering or leaving through the door, the user can collect the pass card from the card detector machine. PCD is connected with microcontroller through SB as shown in Fig. 3. When a pass card is detected, PCD unlocks the door and sends this information to the microcontroller via SB.
E. Mobile Terminal Detector: Mobile Terminal Detector i.e. MTD is attached with the rotating door to detect the presence of an active MT. The MTD checks whether the entrant and exeunt has an active MT [45] or not. If an active MT is detected, MTD informs the microcontroller through SB with which it is connected as shown in Fig. 3.
F. Femtolet: The Femtolet F is connected to the microcontroller as shown in Fig. 3. When the MTD detects an active MT inside the room, it informs the microcontroller via SB. Then the microcontroller informs the Femtolet F and it is turned on. The MTs within the smart room can make call, receive call and access cloud service through the Femtolet F. F is connected to the service provider's network. As a Femtolet has 10–20 m coverage area, it can serve the MTs within the smart room. Users registered under Femtolet can offload their data and application inside the Femtolet because Femtolet has the storage and computation ability.
G. Light: L1, L2 and L3 lights are placed in the room. L4 is placed inside the washroom. L1, L2, L3 and L4 are connected with the microcontroller as shown in Fig. 3. After receiving information from PCD that a pass card is detected, the microcontroller switches on the lights L1, L2 and L3. When the room becomes empty as detected by R and PCD, according to the instructions received from the microcontroller, these lights are switched off. When a person enters into the washroom as detected by POS, the light L4 is turned on by the microcontroller. If no one is present inside the washroom as detected by POS [46], L4 is turned off based on the microcontroller's instructions.
H. Alarm: The alarm A is connected with the microcontroller as shown in Fig. 3. When an emergency situation occurs, the indicator I becomes red and the alarm A rings.
I. Smoke Detector: Smoke detector i.e. SMD is used in the room to detect the presence of smoke generated from fire. SMD is connected with microcontroller through SB as shown in Fig. 3. When smoke is detected inside the room, the SMD informs the microcontroller through SB. The microcontroller in turn activates the alarm.
J. Air-Conditioning Machine: The AC machine is placed inside the smart room. The AC dehumidifies and extracts heat from the room. The AC is connected to the microcontroller as shown in Fig. 3. When a user is detected inside the room by R and PCD, the microcontroller after receiving this information switches on the AC. Similarly when the room becomes empty as detected by R and PCD, the microcontroller turns off the AC.
K. Indicator: The indicator I is placed inside the room. It is connected with the microcontroller as shown in Fig. 3. Three indicating lights, red, yellow, and green, are present. When an emergency case arises, the red light glows, and the alarm becomes active. The yellow light indicates warning situation and the green light indicates normal situation.
L. PIR-Occupancy Sensor: Passive infrared occupancy sensor i.e. POS is placed on the washroom's wall. POS uses passive infrared (PIR) technology to monitor a room for occupancy. POS is connected with the microcontroller through SB as shown in Fig. 3. When a person enters into the washroom, POS inform the microcontroller via SB. The

microcontroller then turns on the light L4. When POS detects that no user exists in the washroom [46], it informs the microcontroller. Then the microcontroller switches off the light L4.

3.3 Working Principle of FBSOSRE

The working principle of proposed FBSOSRE is given as follows:

Proposed Working Model of FBSOSRE

```
Step 1: Set a counter (C) denoting number of user in the room to 0 i.e. C=0 and set anothercounter
        (P) denoting number of person in the room to 0 i.e. P=0.
Step 2:When the PCD detects a valid card,
Step 3:The rotating door is unlocked.
Step 4:If the MTD detects the existence of an active MT, MTD is set to 1 i.e. MTD=1.
Step 5: The rotating door is locked after rotating once in clockwise or in anti-clockwise way.
Step 6:The PCD passes the card to the opposite end of the PCD machine and then it is collected.
Step 7:A) If Rotation == Clockwise,
    a) Set P = P+1.
    b) If P == 1,
        i) Set L1 = on, L2 = on, L3 = on, AC = on, I = green.
        ii) The current room status is saved in record.txt file.
    B)Else if Rotation == Anti-Clockwise,
    a) Set P = P-1.
    b) If P == 0,
        i) The current room status is saved in record.txt file.
        ii) Reset the System.
Step 8:  A)If MTD == 1 &&Rotation == Clockwise,
        a) Set C = C +1.
        b) If C == 1, set F = on.
        c) The current room status is saved in record.txt file.
    B)Else if MTD == 1 &&Rotation == Anti-Clockwise,
        a) Set C = C -1.
        b) If C=0, set F=off.
        c) The current room status is saved in record.txt file.
Step 9: If POS == active,
        a) Set L4 = on and Timer = on.
        b) The current room status is saved in record.txt file.
Step 10: If 15≤ Timer <30,
        a) If A == off || I! = yellow, set I = yellow.
        b) The current room status is saved in record.txt file.
Step 11:If Timer ≥ 30,
        a) If A == off,
            i) Set I = red and A = on.
            ii) The current room status is saved in record.txt file.
Step 12: If SMD == active,
        a) Set I = red and A = on.
        b) The current room status is saved in record.txt file.
```

Explanation of Proposed Working Model of FBSOSRE Whenever the PCD detects a valid pass card, the rotating door is unlocked. When the rotation sensor R detects a clockwise rotation, the value of the counter P is incremented by 1. When the rotation sensor detects an anti-clockwise rotation, the value of P is decremented by 1. When the value of P becomes zero, it is predicted that the room is empty. In that case, the system resets. After the reset state when the system detects the entry of a person inside the room, the lights of the room, AC machine and green light of the indicator are powered on. If a clockwise rotation is detected and MTD detects the presence of an active MT, the Femtolet F is turned on and the counter C is incremented by 1. When the MTD detects exit of an active MT, the value of C is decremented by 1. When the value of C becomes 0, the Femtolet is turned off. Whenever the POS senses the presence of someone inside the attached washroom, the light L4 is turned on and the timer starts. The timer is used for emergency purpose. For the first 14 min the indicator I remains green. When the timer value is 15 min, the indicator turns yellow. When the timer value is 30 min, the indicator I turns red, the alarm A rings. When smoke is detected by SMD in the room, the alarm A and the red light of the indicator I are turned on. The proposed system keeps the detailed record of all the events occurred in the total system in record.txt file. If any device fails, the indicator's red light glows and the alarm A rings.

3.3.1 Data and Application Offloading Facilities for Users in FBSOSRE

The users under FBSOSRE can offload their data and applications inside the Femtolet. As the Femtolet has storage facility, the users when inside the room can store their data inside it. If the user wants to execute applications outside the mobile devices to save battery life, Femtolet can be recommended as a solution. The Femtolet is connected to the remote cloud servers. Use of Femtolet reduces the communication latency and power in offloading because the distance between the requesting device and the Femtolet is much less compared to the distance between the device and the remote cloud servers. If the user requires, the data can be offloaded from the Femtolet to the remote cloud servers. Due to this the user can access the data from the cloud servers staying outside the room.

3.4 Power Consumption of FBSOSRE

The parameters used in calculating the power consumption by the system FBSOSRE are presented in Table 1.The power consumed by an active Femtolet per unit time is given as,

$$P_{FLA} = P_{mp} + P_{fpga} + P_{ram} + P_{rft} + P_{rfr} + P_{pa} + P_{comcl} \tag{1}$$

The power consumed by the FBSOSRE system is given as,

$$\begin{aligned} P_{system} = {} & (P_R \times T_R) + (P_{PCD} \times T_{PCD}) + (P_{POS} \times T_{POS}) \\ & + (P_{MTD} \times T_{MTD}) + (P_I \times T_I) + (P_{AC} \times T_{AC}) + \sum_{N_L} (P_L \times T_L) \\ & + (P_A \times T_A) + (P_{FLA} \times T_{FLA}) + (P_{SMD} \times T_{SMD}) + (P_{MIC} \times T_{MIC}) \end{aligned} \tag{2}$$

As the Femtolet is turned on and off according to active MT's presence in the room, in FBSOSRE only active mode of Femtolet is considered instead of considering both of its active and idle modes.

Table 1 Parameters used in calculation of power consumption

Parameter	Definition
P_R	Power consumed by rotation sensor per unit time
P_{PCD}	Power consumed by PCD per unit time
P_{POS}	Power consumed by POS per unit time
P_{MTD}	Power consumed by MTD per unit time
P_I	Power consumed by indicator per unit time
P_{AC}	Power consumed by AC per unit time
P_L	Power consumed by a light per unit time
P_A	Power consumed by alarm per unit time
P_{FLA}	Power consumed by an active Femtolet per unit time
P_{SMD}	Power consumed by smoke detector per unit time
P_{MIC}	Power consumed by microcontroller per unit time
P_{mp}	Power consumed by microprocessor of Femtolet per unit time
P_{fpga}	Power consumed by field programmable array (FPGA) of Femtolet per unit time
P_{ram}	Power consumed by random access memory (RAM) of Femtolet per unit time
P_{rft}	Power consumed by radio frequency transmitter (RFT) of Femtolet per unit time
P_{rfr}	Power consumed by radio frequency receiver (RFR) of Femtolet per unit time
P_{pa}	Power consumed by power amplifier (PA) of Femtolet per unit time
P_{comcl}	Power consumed by Femtolet in accessing cloud per unit time
T_R	Amount of time the rotation sensor is active
T_{PCD}	Amount of time the PCD is active
T_{POS}	Amount of time the POS is active
T_{MTD}	Amount of time the MTD is active
T_I	Amount of time the indicator is active
T_{AC}	Amount of time the AC is on
T_L	Amount of time the light is on
T_A	Amount of time the alarm rings
T_{SMD}	Amount of time the smoke detector is on
T_{MIC}	Amount of time the microcontroller operates
T_{FLA}	Amount of time the Femtolet is in active mode
N_L	Number of light in the room

4 Simulation Analysis of FBSOSRE

The proposed FBSOSRE architecture is simulated using network simulator Qualnet7. The parameters used in simulation are given in Table 2 and the simulation model is presented in Fig. 4.

Table 2 Simulation parameters

Layer	Parameter	Value
Physical layer	Radio type	802.11b radio
	Packet reception model	PHY 802.11b reception model
	Antenna model	Omni directional
	Temperature	290.0 K
	Noise Factor	10.0
	Energy model	Sensor nodes: MicaZ Sensor base station: MicaZ Microcontroller: MicaZ Detectors: MicaZ Mobile device: user specified Femtolet: user specified Cloud: user specified
MAC layer	MAC protocol	802.11
Network layer	Network protocol	IPV4
	Routing protocol	Bellman Ford
Transport layer	Sending and receiving buffer size (bytes)	Sensor nodes: 512 Sensor base station: 512 Microcontroller: 512 Detectors: 512 Mobile device: 512 Femtolet: 8162 Cloud: 16,384
Battery model	Battery model	Linear model
	Battery change monitoring interval	60 s
	Full battery capacity (mAh)	1200
Scenario properties	Simulation time (s)	300
CBR properties	Item size (bytes)	512

4.1 Delay of FBSOSRE

The time taken to transfer the data from the sender to the receiver is called delay and it is measured in seconds (s). The average delays of the nodes used in FBSOSRE are shown in Table 3 and Fig. 5. The amount of data transmission is 51,200–204,800 bytes.

As the sensor base station acting as node 4 receives data from all the sensor nodes and forwards to the microcontroller, the delay is more at the sensor base station. As Femtolet acting as node 9, provides offloading to the mobile devices registered under it, all the processing related to mobile user data takes place inside it. Due to this reason the delay is more in case of Femtolet and sensor base station. This is also demonstrated in Table 3 and Fig. 5.

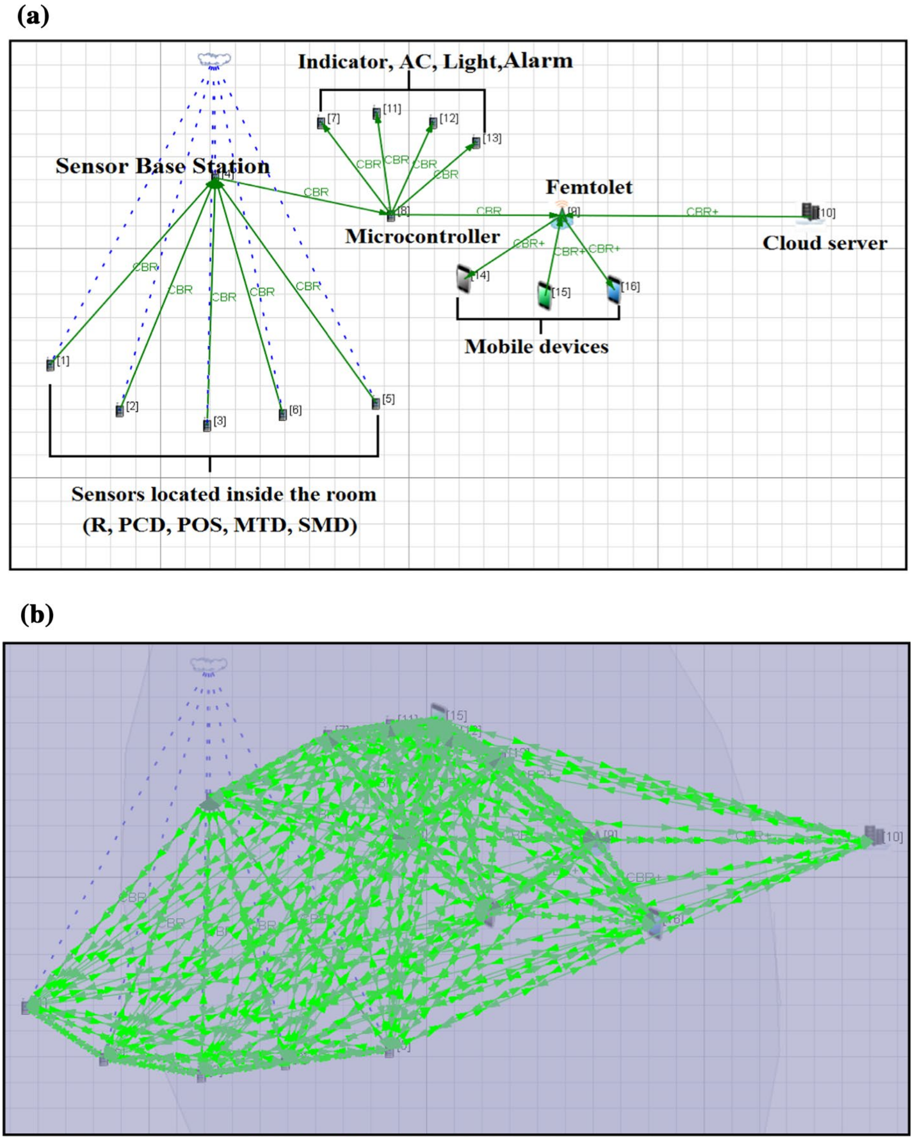

Fig. 4 FBSOSRE scenario created using Qualnet7. **a** FBSOSRE simulation scenario created in Qualnet7 (alarm spell correction), **b** FBSOSRE scenario during simulation in Qualnet7

Table 3 Delay of FBSOSRE

Nodes	Node ID	Average delay (s)			Total delay (s) of the system		
		51,200 bytes	102,400 bytes	204,800 bytes	51,200 bytes	102,400 bytes	204,800 bytes
Sensor nodes located inside the room (R, PCD, POS, MTD, SMD)	1	0.00186	0.00187	0.00195	0.03222	0.03551	0.0449
	2	0.00186	0.00187	0.00197			
	3	0.00186	0.00187	0.00197			
	5	0.00186	0.00187	0.00196			
	6	0.00186	0.00187	0.00195			
Sensor base station	4	0.00277	0.00395	0.0069			
Indicator, AC, light, alarm	7	0.00192	0.002	0.0023			
	11	0.00189	0.00195	0.0021			
	12	0.00189	0.00199	0.0021			
	13	0.00192	0.002	0.0022			
Microcontroller	8	0.002	0.0022	0.003			
Femtolet	9	0.00277	0.0038	0.007			
Mobile devices registered under femtolet	14	0.00197	0.0021	0.0022			
	15	0.00189	0.00197	0.0021			
	16	0.0019	0.002	0.0022			
Cloud server	10	0.002	0.0022	0.003			

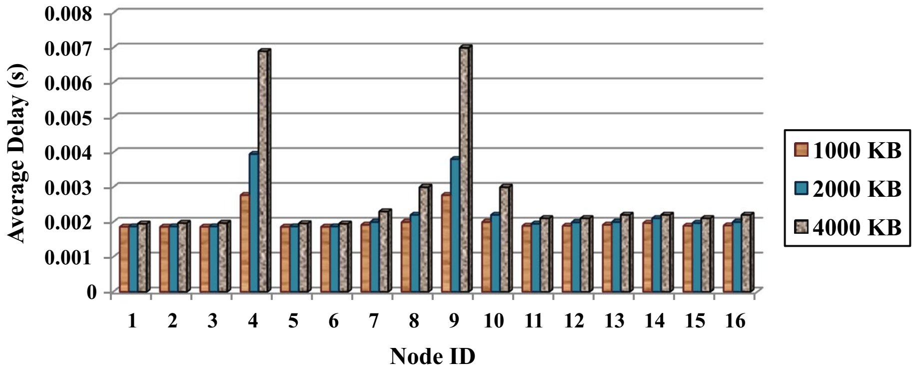

Fig. 5 Average delay of nodes used in FBSOSRE

4.2 Jitter of FBSOSRE

The difference between the transmission delay of the current packet and transmission delay of the previous packet is called jitter and it is measured in second. The average jitters of the nodes of FBSOSRE are presented in Table 4 and Fig. 6. The amount of data transmission is 51,200–204,800 bytes. The sensor base station which is node 4 receives data from the sensor nodes and conveys to the microcontroller. As a result the jitter is high in this case. The data of mobile users present in the room are processed inside the Femtolet i.e. node 9. Consequently the jitter becomes high as shown in Table 4 and Fig. 6.

4.3 Carried Load of Nodes

The carried loads by the nodes of FBSOSRE are presented in Table 5 and Fig. 7. It is measured in bits/sec. The amount of data transmission is 51,200–204,800 bytes.

As the microcontroller i.e. node 8 operates the entire system, the carried load is higher than the other devices, and this is observed from Table 5 and Fig. 7.

Table 4 Jitter of FBSOSRE

Nodes	Node ID	Average jitter (s)			Total jitter (s) of the system		
		51,200 bytes	102,400 bytes	204,800 bytes	51,200 bytes	102,400 bytes	204,800 bytes
Sensor nodes located inside the room (R, PCD, POS, MTD, SMD)	1	0.00027	0.00029	0.00039	0.00624 s	0.00901	0.01976
	2	0.00028	0.0003	0.0004			
	3	0.00027	0.0003	0.0004			
	5	0.00027	0.0003	0.00038			
	6	0.00027	0.00029	0.0004			
Sensor base station	4	0.0009	0.00183	0.00466			
Indicator, AC, light, alarm	7	0.00033	0.00047	0.0008			
	11	0.0003	0.00035	0.00062			
	12	0.00029	0.00038	0.00064			
	13	0.00032	0.0004	0.00069			
Microcontroller	8	0.00042	0.00063	0.0016			
Femtolet	9	0.00089	0.0015	0.0052			
Mobile devices registered under femtolet	14	0.00038	0.00047	0.00077			
	15	0.0003	0.00038	0.00061			
	16	0.0003	0.00052	0.0007			
Cloud server	10	0.00045	0.0006	0.0015			

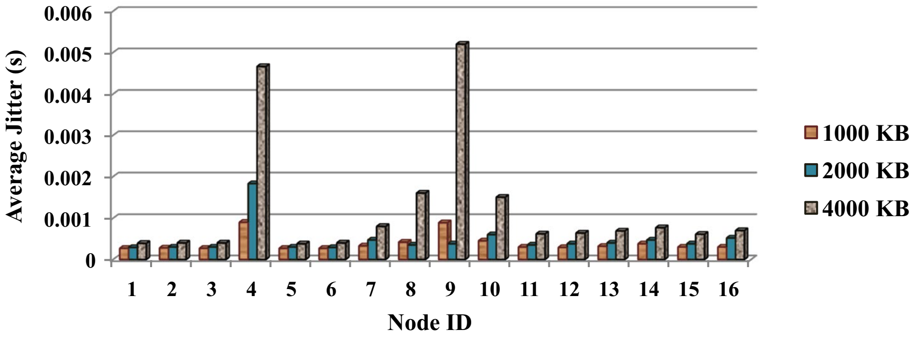

Fig. 6 Average jitter of nodes used in FBSOSRE

4.4 Unicast Received Throughput of FBSOSRE

Throughput can be explained as the average rate of successfully delivered message through a network. The measurement unit of throughput is bits/sec. Unicast received throughputs of the receiving nodes in FBSOSRE are presented in Table 6 and Fig. 8. The amount of data transmission is 51,200–204,800 bytes. As observed from Table 6 and Fig. 8, the throughput of node 4 i.e. sensor base station and node 9 i.e. Femtolet is high.

4.5 Energy Consumption of Nodes

Total energy consumptions of all the nodes of FBSOSRE are presented in Table 7 and Fig. 9. Total energy consumption of a node is determined by summing up the energy consumed by it in transmit and receive modes. The amount of data transmission is 51,200–204,800 bytes.

As observed from Table 7 and Fig. 9, the microcontroller i.e. node 8 consumes higher energy than the other devices. This is because the microcontroller operates the entire system.

4.6 Summary of Simulation Results

Based on the results Table 8 is generated to show the total and mean values of the parameters measured from the simulation of the system FBSOSRE.

4.7 Comparison of Delay and Energy Consumption in Cloud Service Access Using Femtocell and Femtolet

Femtolet itself is able to provide cloud services. But if it fails to meet the user's need, it accesses the cloud and serves the user. In that case, offloading takes place inside the cloud.

Table 5 Carried load of FBSOSRE

Nodes	Node ID	Average Carried load (bits/s)			Total Carried load (bits/s) of the system		
		51,200 bytes	102,400 bytes	204,800 bytes	51,200 bytes	102,400 bytes	204,800 bytes
Sensor nodes located inside the room (R, PCD, POS, MTD, SMD)	1	288.23	370.917	504.56	4768.428	6340.193	8878.446
	2	288.53	371.32	504.96			
	3	288.22	370.91	504.55			
	5	288.4	371.1	504.74			
	6	288	370.69	504.33			
Sensor base station	4	288.7	371.52	504.16			
Indicator, AC, light, alarm	7	236.37	236.226	236.226			
	11	236.37	236.23	236.23			
	12	236.53	236.44	236.44			
	13	236.37	236.23	236.23			
Microcontroller	8	495.6	909.502	1577.78			
Femtolet	9	443.9	775.098	1309.65			
Mobile devices registered under femtolet	14	288.225	370.9	504.55			
	15	288.375	371.1	504.74			
	16	288.378	371.11	504.75			
Cloud server	10	288.23	370.9	504.55			

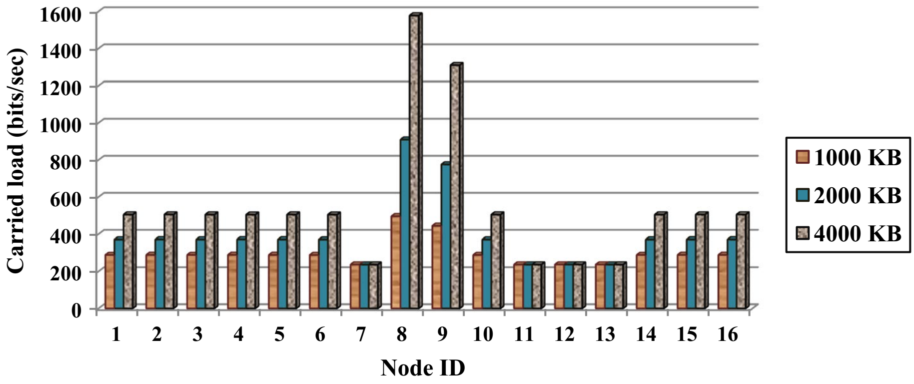

Fig. 7 Carried load of nodes used in FBSOSRE

The probability of offloading to the Femtolet is considered as probability of hit (P_{hit}) and the probability of offloading to cloud through Femtolet is considered as probability of miss (P_{miss}), where $P_{miss} = 1 - P_{hit}$. Let the delay in offloading to Femtolet is D_{FL} and the delay in offloading to cloud is D_{cl}.

Then the delay considering both hit and miss is given as,

$$D = P_{hit} \times D_{FL} + (1 - P_{hit}) \times D_{cl} \tag{3}$$

Let the energy consumption in offloading to Femtolet is E_{FL} and the delay in offloading to cloud is E_{cl}. Then the delay considering both hit and miss is given as,

$$E = P_{hit} \times E_{FL} + (1 - P_{hit}) \times E_{cl} \tag{4}$$

Figure 10 shows the delay of accessing cloud service by a mobile device using Femtolet determined using Eq. (3) and using femtocell. The amount of data access is 100–400 KB. As observed from Table 6 and Fig. 8, the throughput of node 4 i.e. sensor base station and node 9 i.e. Femtolet is high. It is observed from Fig. 10 that Femtolet reduces the delay by approximately 8–35% than the femtocell. Figure 11 shows the energy consumption in accessing cloud service by a mobile device using Femtolet determined using Eq. (4) and using femtocell. The amount of data access is 100–400 KB. It is observed from Fig. 11 that Femtolet reduces the energy consumption by approximately 14–57% than the femtocell.

As Femtolet is containing a cloud platform, it is able to offload data or computation as requested by the user. But femtocell is not able to do it as it does not have a cloud platform. As a result, each time the user requests for offloading data or computation, it takes place inside the cloud through the femtocell which increases delay as well as energy consumption. By reducing the energy consumption, Femtolet builds a green smart room environment.

Table 6 Unicast received throughput of FBSOSRE

Nodes	Node ID	Average unicast received throughput (bits/s)			Total unicast received throughput (bits/s) of the system		
		51,200 bytes	102,400 bytes	204,800 bytes	51,200 bytes	102,400 bytes	204,800 bytes
Sensor base station	4	21,368.4	42,762.6	85,650.1	81,199.41	162,421.7	324,923.5
Indicator, AC, light, alarm	7	4275.22	8548.47	17,090.4			
	11	4273.31	8548.26	17,101.4			
	12	4273.35	8548.45	17,101.4			
	13	4273.95	8550.52	17,104.3			
Microcontroller	8	4270.22	8531.87	17,031.8			
Femtolet	9	21,381.1	42,739.1	85,367.4			
Mobile devices registered under femtolet	14	4270.81	8552.78	17,120			
	15	4272.05	8546.43	17,098			
	16	4270.17	8542.41	17,142			
Cloud server	10	4270.83	8550.76	17,116.7			

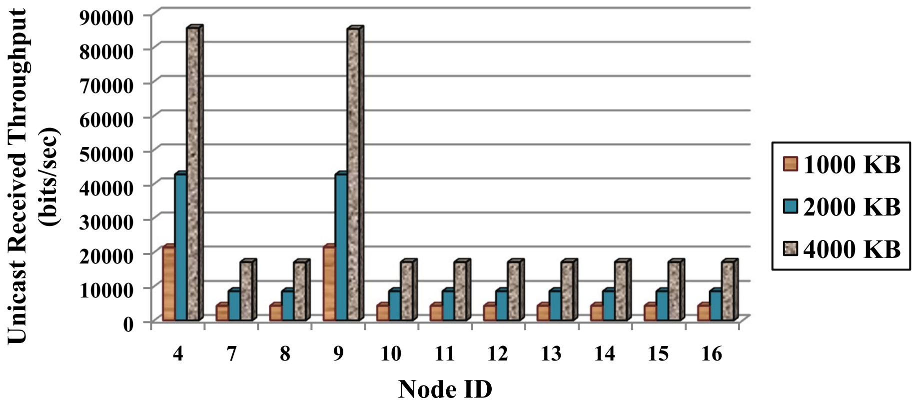

Fig. 8 Average unicast received throughput of nodes used in FBSOSRE

5 Comparison of Proposed Model with Existing Works on Femtocell Based Smart Room

The proposed smart room FBSOSRE is compared with the existing femtocell based smart home/room models and presented in Table 9 to demonstrate the novelty of our work.

6 Conclusion

In this paper, we have proposed architecture of a smart room where mobile cloud network device Femtolet is used as an amalgamation of cloud platform with the components of femtocell. In the proposed scenario, a microcontroller receives status of the objects located inside the room using sensor nodes and then activates and controls other devices present in the room. The devices are activated by the microcontroller based on user's existence inside the room for the purpose of effective utilization of the devices. In the proposed architecture, Femtolet which is a home base station with cloud platform is used to offer communication and computation simultaneously to the user residing in the room. The architecture of the proposed smart room environment is implemented using Qualnet7. Simulation results demonstrate that using Femtolet the delay is reduced by approximately 8–35% than the femtocell base station. Simulation results show that using Femtolet the energy consumption is reduced by approximately 14–57% than the femtocell to create a green environment. Hence it can be concluded that through the use of Femtolet the proposed green smart room provides low power and high speed cloud services to the users.

Table 7 Energy consumption of FBSOSRE

Nodes	Node ID	Total energy consumption (mWh)			Total energy consumption (mWh) of the system		
		51,200 bytes	102,400 bytes	204,800 bytes	51,200 bytes	102,400 bytes	204,800 bytes
Sensor nodes located inside the room (R, PCD, POS, MTD, SMD)	1	0.121	0.1423	0.1965	9.59	11.3408	15.8852
	2	0.121	0.1423	0.1966			
	3	0.121	0.1423	0.1965			
	5	0.12	0.1423	0.1966			
	6	0.12	0.1423	0.1963			
Sensor base station	4	0.13	0.1533	0.214			
Indicator, AC, light, alarm	7	0.872	1.037	1.4482			
	11	0.878	1.037	1.448			
	12	0.878	1.037	1.448			
	13	0.878	1.037	1.448			
Microcontroller	8	0.903	1.074	1.52			
Femtolet	9	0.9	1.075	1.518			
Mobile devices registered under femtolet	14	0.889	1.045	1.4625			
	15	0.889	1.045	1.463			
	16	0.889	1.045	1.463			
Cloud server	10	0.881	1.044	1.47			

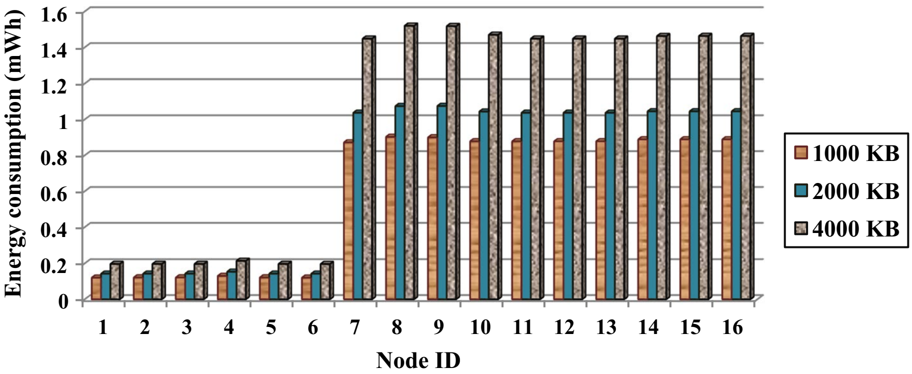

Fig. 9 Energy consumption ofthe nodes used in FBSOSRE

Table 8 Summary table of simulation results

Parameter	Obtained value
Delay	0.03222–0.0449 s (for 1000–4000 KB data transmission)
Jitter	0.00624–0.01976 s (for 1000–4000 KB data transmission)
Carried load of nodes	4768.428–8878.446 bits/s (for 1000–4000 KB data transmission)
Unicast received throughput	81199.41–324923.5 bits/s (for 1000–4000 KB data transmission)
Energy consumed	9.59–15.8852 mWh (for 1000–4000 KB data transmission)

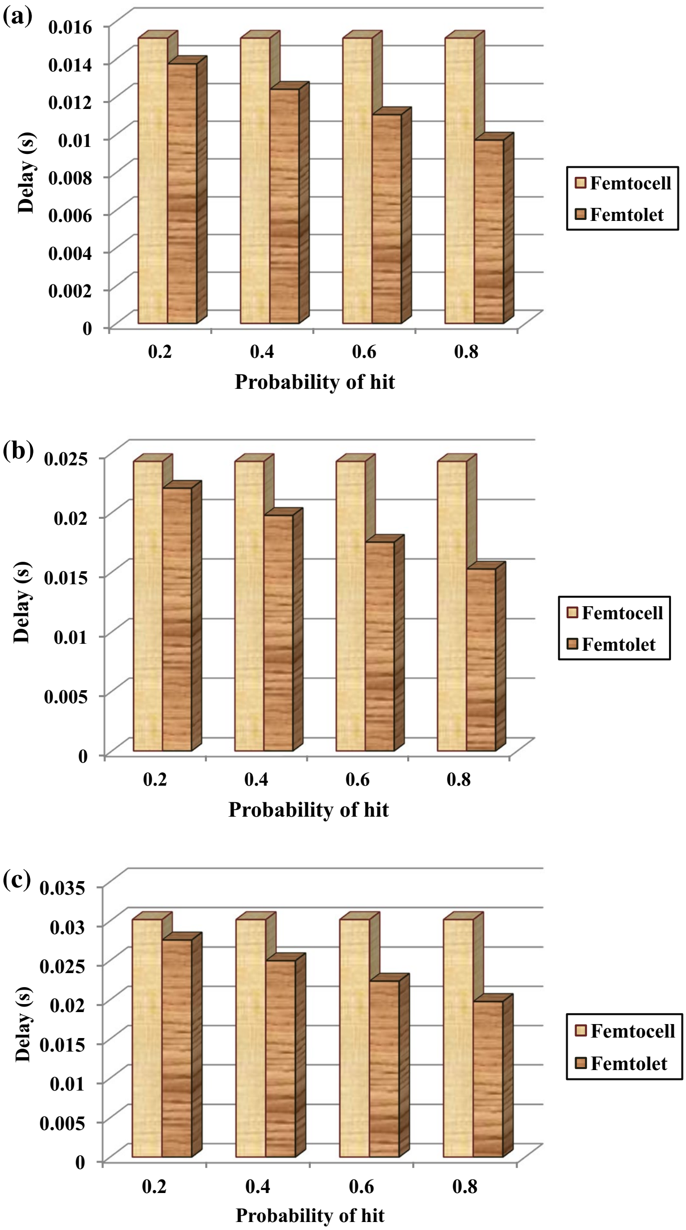

Fig. 10 Delay (s) of Femtolet in accessing cloud service. **a** Delay (s) of Femtolet in accessing cloud service when amount of data access is 100 KB, **b** Delay (s) of Femtolet in accessing cloud service when amount of data access is 200 KB, **c** Delay (s) of Femtolet in accessing cloud service when amount of data access is 400 KB

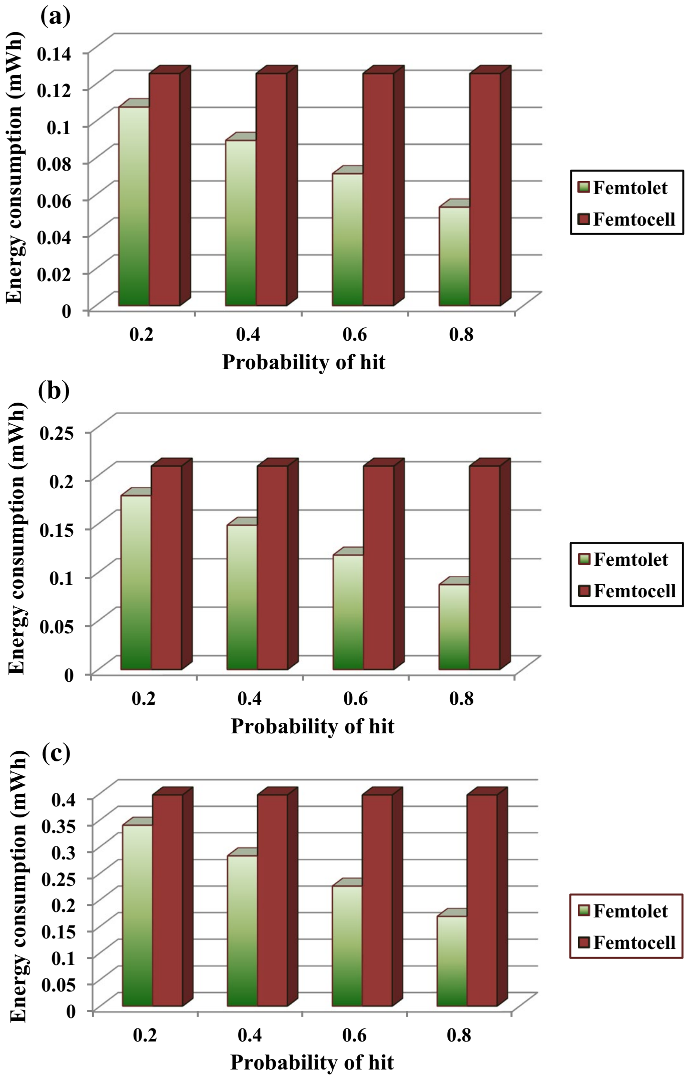

Fig. 11 Energy consumption (mWh) of Femtolet in accessing cloud service. **a** Energy consumption (mWh) of Femtolet in accessing cloud service when amount of data access is 100 KB, **b** Energy consumption (mWh) of Femtolet in accessing cloud service when amount of data access is 200 KB, **c** Energy consumption (mWh) of Femtolet in accessing cloud service when amount of data access is 400 KB

Table 9 Comparison between proposed and existing works on femtocell based smart room

Feature	Existing works on femtocell based smart home/room				Proposed FBSOSRE model
	Use of wireless sensor network based on multilevel femtocells for home monitoring [21]	Home service management using local breakout mechanisms in a femtocell [36]	Femtocell based indoor region [38]	Integration of femtocell with home appliances [39]	
Working model	Body sensor, ambient sensor and gas sensor are combined for home monitoring using femtocell base station	Home services are combined at the femtocell access point and provided to the mobile devices under the coverage of the femtocell	Femtocell is used inside the room to provide better communication with improved signal quality	Femtocell is connected with the home appliances present in the room. Femtocell enhances the signal quality	Smart room architecture with 5G network device Femtolet is proposed where the smart devices work in a self-organized way to offer a smart environment within the room. Femtolet simultaneously provides good signal strength and high speed cloud services at low power to the mobile users present in the room
Smart environment is created	✓	✓	✓	✓	✓
Smart home base station is used	✓	✓	✓	✓	✓
Cloud platform is integrated with home base station for offloading	×	×	×	×	×
Energy consumption in cloud service access is reduced	×	×	×	×	×
Delay in cloud access is reduced	×	×	×	×	×
Remarks	The proposed approach is novel as well as better than the existing works from the perspective of power consumption and delay				

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