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Author/s:

Mukherjee, A;De, D;Buyya, R

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De Debashis (Orcid ID: 0000-0002-9688-9806)
Buyya Rajkumar (Orcid ID: 0000-0001-9754-6496)

E²R-F²N: Energy Efficient Retailing using Femtolet based Fog Network

Anwesha Mukherjee¹, Debashis De^{2,3}, and Rajkumar Buyya⁴

¹Department of Computer Science and Engineering,
Indian Institute of Technology (IIT) Kharagpur, West Bengal 721302, India.

²Centre of Mobile Cloud Computing, Department of Computer Science and Engineering,
Maulana Abul Kalam Azad University of Technology, West Bengal,
B.F.-142, Salt Lake, Sector-1, Kolkata-700064, India.

³Department of Physics, University of Western Australia,
35 Stirling Hwy, Crawley WA 6009, Australia.

⁴Cloud Computing and Distributed Systems (CLOUDS) Laboratory
School of Computing and Information Systems
The University of Melbourne, Australia.

dr.debashis.de@gmail.com

Summary

Energy efficient smart retail system design is a challenging research area. In this paper, we propose an automated retail system using femtolet based fog network. Femtolet is an indoor base station providing computation and storage. Femtolets in our system work as indoor base stations as well as maintain databases of the products located in their respective coverage areas. The femtolets switch to active or idle mode according to user's presence in its coverage. A smart trolley is proposed for our retailing system, which guides the user to the particular product type selected by the user. The user after entering into the shopping mall carries the smart trolley. The customer selects and purchases product using this trolley. Based on product purchasing, the respective databases maintained inside the femtolets are updated. An Android application for the proposed retailing is developed. We compare the power consumption and delay of the proposed retail system with the existing retail system. The simulation analyses illustrate that the proposed approach reduces the power by approximately 89% and 94% respectively than the local and remote cloud servers based retail systems. Thus, we refer the proposed system as a green retail

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system. The performance of the proposed system through experimental analysis is also evaluated.

KEY WORDS

Retail, Sensor, Femtolet, Smart trolley, Power.

1 INTRODUCTION

The explosive growth in the digital industry has made the people busier. Effective utilization of time is now vital for everyone. When a user visits a shopping mall for the first time, to select a product from a shop inside the mall, the customer has to take help of the personnel working in the shop. In few shopping malls nowadays a large screen display is provided regarding the products in the shopping malls. But this may not help the user to locate the product type which he/she is looking for. People of today's world are familiar with smart phone which contains a Global Positioning System (GPS) inside, which can guide the user to the product if a smart application is developed. An augmented reality based smart retail system has been proposed¹. An interactive smart retail system has been discussed². Though researches have been focused on smart city, smart room, smart health, etc. with energy-efficiency, design of green and smart retail system has not been yet largely explored. This paper focuses on this area.

To provide seamless connectivity to the Internet, shopping mall contains wi-fi access points inside. User's smart phone is resource hungry; to execute an application or to store large volume data, smart phone may be infeasible due to poor battery life or limited storage and computation power. As a solution mobile cloud computing (MCC) offers data and application offloading to the mobile devices^{3,4}. In data offloading the users store and access data outside their mobile devices but inside the cloud servers^{5,6}. In application offloading exhaustive applications execute inside the cloud servers and users receive the result using their devices^{7,8}. Remote cloud server is located far from the mobile device; access to the remote cloud servers may cause increase in propagation and communication delays and power consumptions. Cloudlet by working as an agent between mobile device and cloud servers solves this problem^{9,10,11,12}. Femtolet has been proposed for providing communication and computation both to the mobile devices under its coverage¹³. It is an indoor base station containing large storage and having processing power. Femtolet contains the components of femtocell¹⁴ and cloudlet, and it has the features of both. Femtocell is a home node base station (HNB) with low transmission power and it is used for providing good signal level at indoor region^{15,16,17}. For energy and latency aware offloading fog computing has been introduced^{18,19,20,21}. In a fog network, the intermediate devices between mobile device and cloud servers are used to process data. We have used femtolet as a fog device for data and computation offloading in previous work²².

In a shopping mall to maintain the product data private cloud servers or work stations are used.

The shopping mall admin may store the data inside the remote cloud servers; when the product list is updated the data stored at the local servers are also updated. The users visiting the shopping mall either manually picks up products and puts into trolley, and waits in the counter for billing, or accesses the product data at server side, picks the product and puts into e-trolley, and make payment digitally. But in the both the cases, the user accesses the product data at server side through either access point or base station. If Femtolet Based Fog Network (F^2N) is used, the users can directly access the product information inside the femtolet as it is an indoor base station. Femtolet provides data and application offloading to the registered users inside its coverage. In this paper we propose a smart retail system by using femtolet as a fog device. Femtolets are deployed at the floors of the shopping malls according to their coverage and capacities. A femtolet can cover 10-20 m area and serve up to 32 users at a time^{13,22}. In our system each femtolet maintains the databases of the products which are present under its coverage. These femtolets are connected with the local cloud servers.

Delay and energy are two important parameters in the field of computing. Customers of different geographical regions have different requirements. The shopping centers of different regions contain products according to customers' requirement. Storing product database inside the remote cloud data centre and access to the database according to product purchase enhances the delay and energy consumption. Our motivation is to propose a smart retail system which will reduce the delay as well as power consumption.

The key contributions of this paper are as follows:

1. To provide retailing in a shopping mall without manual guidance, we propose a smart system for Energy-Efficient Retailing using Femtolet Based Fog Network (E^2R-F^2N). In the proposed system using a smart trolley a customer can select and purchase product after entering into a shopping mall. An Android App for E^2R-F^2N is created and the product selection through the app is illustrated.
2. For reducing delay and power consumption fog device is used instead of remote cloud servers. Femtolet is an indoor base station with computation ability and storage. It is used as fog device. By maintaining the product database inside the fog device access to remote cloud servers is avoided in order to save power and delay. Through simulation and experimental analyses it is illustrated that the proposed system reduces power and delay to improve the user experience.

The rest of the paper is organized as follows: Section 2 discusses on related works, Section 3 proposes the architecture and working principle of E^2R-F^2N , Section 4 describes the app of E^2R-F^2N , Section 5 discusses on the power and delay consumption of E^2R-F^2N , Section 6 presents the results and analyses, section 7 provides future research directions and Section 8 concludes the paper.

2 RELATED WORK

Smart and automated system design has become an emerging research domain in last few years²³. Researchers have focused on smart home, smart city, smart health monitoring, intelligent surveillance systems²⁴ etc. Nowadays Internet of Things (IoT) is playing a vital role in developing smart system²⁵. Integration of IoT and cloud for smart city development has been discussed²⁵. In such an integrated system the IoT devices i.e. sensor nodes collect object status and data processing and storage occurs inside the cloud servers. For energy efficiency and latency optimization, fog computing has been introduced^{18,19,20,21}.

Electronic commerce (E-Commerce) is very popular today. But smart retail system design has not been yet focused in a large extent. Nowadays people are familiar with online shopping. But for daily needed commodities people still prefer to visit shopping centres. For existing retail systems the product related data are stored and processed inside the local servers or remote cloud servers. The employees of shopping centres guide the customers and product purchase and payment are made manually, especially in underdeveloped countries. If an automated retail system is developed, the customers' time can be saved. The customers' experience on smart technology in retail systems has been studied^{26,27,28}. Augmented reality based a smart retail system has been proposed¹; here the user is guided based on product location and the route towards the product in the store, using deep learning. An interactive smart retail system has been discussed². Machine-readable image and user gesture based retail system has been discussed²⁹. The IoT based business model has been discussed³⁰. A retail shopping application has been discussed³¹. The future of retailing in relation to different issues such as visual display, big data, data analytics, profitability etc has been illustrated³². The relation of retail with big data and data analytics has been discussed in another research work³³. A service oriented architecture for retail has been discussed³⁴. In this system the data storage and processing occur inside the cloud instances. A smart vending machine based on IoT has been proposed³⁵. The user can order products using smart phone without interaction with vending machine in this system³⁵. For physically disabled users augmented reality based smart system has been discussed³⁶, which provides the disable user to shop independently.

Data and application offloading are two vital areas of mobile cloud computing with respect to energy and latency optimization^{3,4}. Use of fog devices for latency and energy efficient code offloading has been discussed²². A simulation toolkit for fog computing, edge computing and IoT has been proposed³⁷, whereas for cloud computing environment a simulation toolkit has been proposed³⁸. Privacy and security are important factors in networking. For privacy preservation in IoT a dynamic protection model has been proposed³⁹. A fully homomorphic encryption solution based on blend arithmetic over real numbers has been proposed⁴⁰. For high level security transmission based on multi-channel communications a method has been proposed⁴¹. A smart city framework based on fog computing has been proposed⁴². An energy efficient architecture for fog computing has been proposed⁴³. A peer-to-peer network based on fog computing has been discussed⁴⁴. A searching method has been also discussed to achieve efficiency with respect to

delay and bandwidth⁴⁴. A routing algorithm for fog based wireless sensor network has been proposed⁴⁵. Reduction of latency improves the Quality of Service (QoS). For improving QoS selection of cloudlet in an energy-efficiency way a fifth generation mobile network device femtolet has been proposed¹³, which has been used as a fog device in another work²². Femtolet is a device that posses the features of femtocell¹⁴ and cloudlet¹². Cloudlet reduces the energy and latency than remote cloud servers while offloading computation¹². In this paper we propose a smart retail system using femtolet based fog network, where the retail data offloading is occurred inside the fog device instead of cloud servers, to reduce power and delay. The comparison of contributions in proposed work with the existing retail systems are provided in TABLE 1. Through this comparison of existing works with ours, we observe that our proposed retail system is novel and useful than the existing retail systems.

TABLE 1 Comparison of contributions of proposed work with existing retail systems

Features	Retail systems and applications				
	Augmented reality based retail ¹	Smart retail ²	Retail based on machine-readable image and user gesture ²⁹	Augmented reality based retail for physically disabled users ³⁶	Proposed E ² R-F ² N
Contributions	Based on augmented reality a retail system is proposed. User's location along with his/her surrounding is captured using user's mobile device; using this image the route towards	Based on user's preferences personalized contents are delivered through large display. In this work digital content, visualization technologies are integrated with interactivity to improve customer's experience.	Based on user gesture and machine readable image a retail scheme is proposed. The machine readable image is compared with user gesture to predict the association of the user with the product of the image.	This system is based on augmented reality and radio frequency identification. For physically disabled persons a hand held device is provided through which the user selects the product.	A fog computing based retail system is proposed. A smart trolley is introduced which contains sensor nodes and microcontroller. The user using smart phone and this trolley selects and purchases products. The route towards the required product is also provided to the

	product required by the customer is provided through deep learning.				user through the retail app. The product databases are maintained inside the fog device femtolet with which the smart phone is connected. These databases are updated according to product purchase.
User interactive retail system	✓	✓	✓	✓	✓
Route towards the product from user's location is provided	✓	×	×	✓	✓
Fog computing	×	×	×	×	✓
Access point/base station works as fog device	×	×	×	×	✓
Power consumption by smart phone is considered	×	×	×	×	✓
Delay is considered	×	×	×	×	✓

3 PROPOSED RETAIL SYSTEM

In this section, we discuss the 3-tier architecture of E^2R-F^2N with its working principle. The mathematical modeling is also described.

3.1 Architecture of E²R-F²N

The three-layer architecture is pictorially shown in FIGURE 1 and discussed as follows.

3.1.1 Layer 1: Sensor-Mobile Layer with Smart Trolley and Mobile Device

Layer 1 is composed of a smart trolley equipped with sensor nodes, microcontroller, a bulb and a mobile device (smart phone). The customer takes a smart trolley after entering into the shopping mall. As soon as the user touches the trolley, the sensor detects human touch and sends a signal to the microcontroller. The microcontroller then sends a message to the mobile device. As soon as the message is received, an android app is opened on the screen of mobile device, showing a welcome note. After that the app asks the user to enter his/her username and password. If the user has already an account, he/she logs in to the account. Otherwise the user creates a new account, following by user id and password creation. After successful login, the product category list is opened by the app on the mobile screen, where the customer can easily find his/ her needed commodity. When a user selects an item category, the GPS tracker in the mobile device tracks the location and a route towards the selected item category is displayed on the mobile screen. Using this route the user moves towards the item rack; after reaching the location, the user picks item. If the user puts the item in the trolley, the weight measurement sensor detects change in the weight and sends a signal to the microcontroller. The microcontroller sends a signal to the connected bulb and the mobile device; after receiving signal the bulb glows red and an option appears on the mobile screen asking the user if he/she wants to buy the item. If the user clicks on yes, the user is asked to enter the barcode using the scanning device. After the correct barcode is entered, a screen will appear showing the option to make online payment. The user makes payment through digital wallet and after successful payment the mobile device sends a message to the microcontroller. The microcontroller sends a signal to the bulb, which then glows green. If the payment is not made successfully, the bulb remains red. If user wants to buy more items, then the user has to continue in same way.

3.1.2 Layer 2: Fog Computing Layer with Femtolet, Security-Gateway and HNB-Gateway

Layer 2 is composed of femtolet, Security-Gateway (Se-GW) and Home Node Base Station-Gateway (HNB-GW). The mobile device is connected to the femtolet. The femtolet contains database of the products located in its coverage area. The product database is updated based on purchase of product. The quantity of each product is maintained in the database. When a product quantity reaches to 0, the femtolet sends this information to the local cloud via Se-GW and HNB-GW. The updated product database is sent to the local cloud servers through Se-GW and HNB-GW at a time interval. As the database update takes place inside the intermediate device femtolet, it is referred as a fog device. The user when makes payment digitally, the

communication is performed through the use of femtolet. The femtolet is connected with the network through Se-GW, which passes the information through a security tunnel. The security algorithms used for femtolet and cloud servers are discussed in section 3.3.

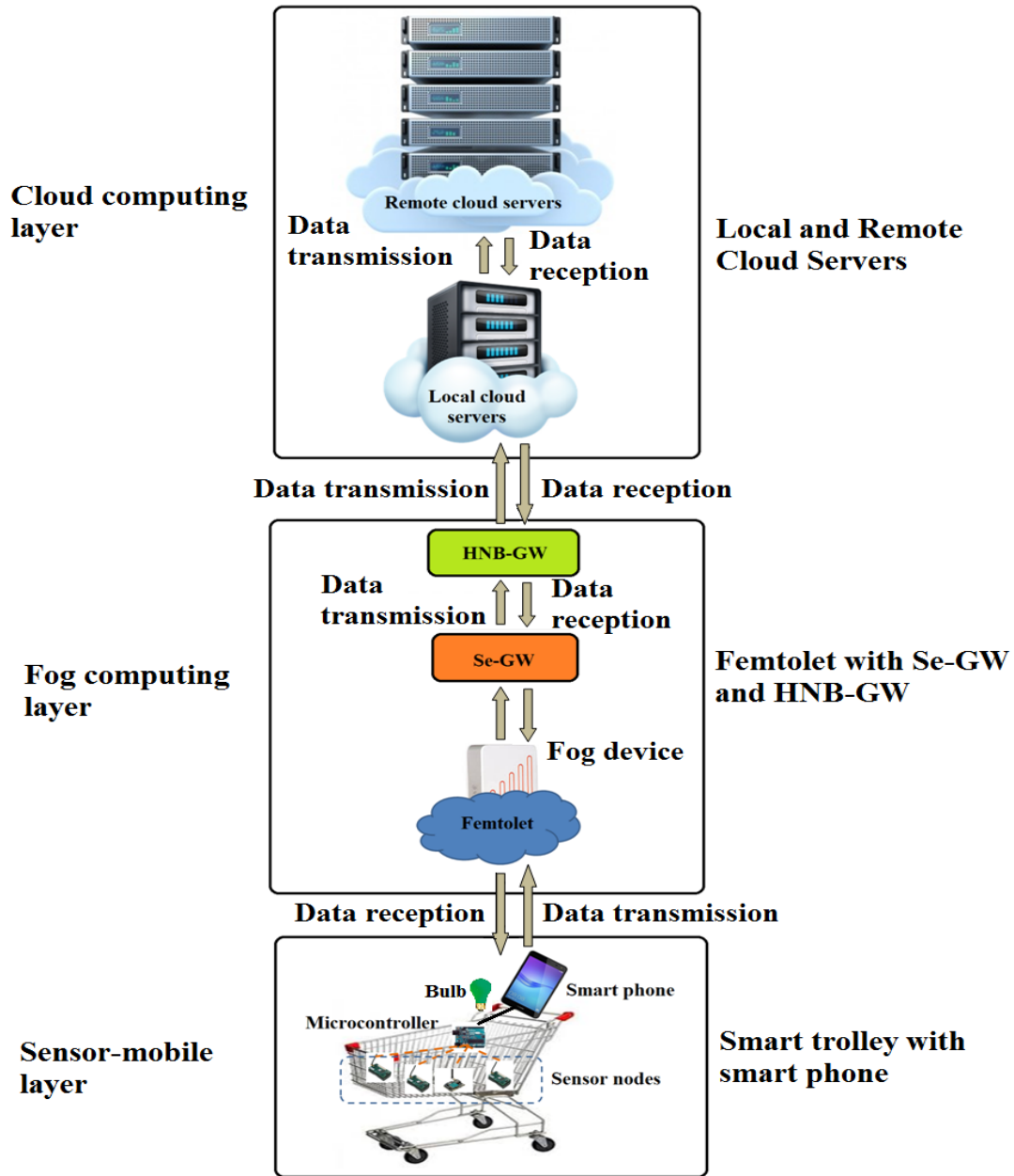


FIGURE 1. Three-layer architecture of E²R-F²N

3.1.3 Layer 3: Cloud Computing Layer with Local and Remote Cloud Servers

Layer 3 is composed of local and remote cloud servers. The local cloud is connected with all the femtolets deployed in various floors of the shopping mall. These femtolets send their respective product databases to the local cloud at a time interval. Therefore the local cloud has all the product databases for the shopping mall. The local cloud server is connected with the remote cloud servers. When the local cloud receives a message from a femtolet that a product quantity has reached to 0, the local cloud sends an order message to the registered mobile device of the product vendor agency for sending the products. The shopping mall data if the admin wishes can maintain inside the remote cloud servers. When any discount or similar offers are launched in the shopping mall, advertisements on the social networking sites about these offers are displayed.

3.2 Working Principle of E²R-F²N

FIGURE 2 shows the working model of proposed E²R-F²N.

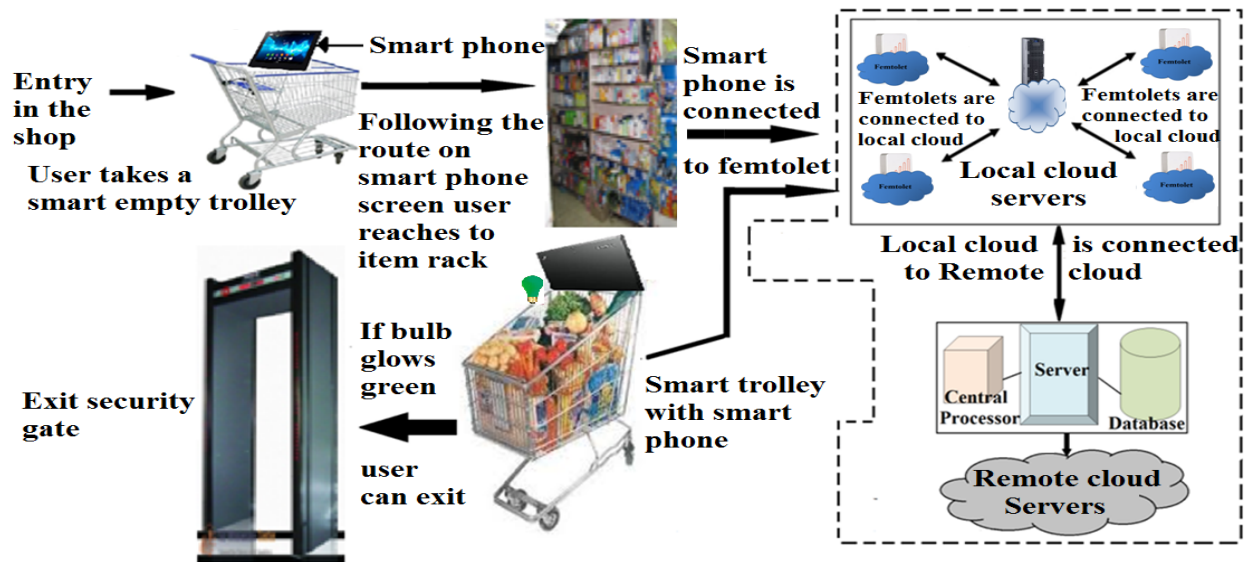


FIGURE 2. Proposed retail system using E²R-F²N

The user after entering into the shopping centre takes the smart trolley and places the smart phone. Using proposed system, the user reaches to the product location and picks product from the rack. If the user purchases the product, payment is made through digital wallet, and the product databases maintained inside the femtolet covering that region of the centre is updated. Whenever products are purchased by the customers corresponding product database maintained in the respective femtolets are updated. These femtolets after a time interval send the updated product databases to the local cloud servers of the shopping centre. The local cloud servers are

connected with remote cloud servers. When the user makes payment for all the products placed in the trolley, the bulb glows green and the user is allowed to exit the shopping centre. The working model of E²R-F²N is illustrated in algorithm 1.

Algorithm 1: Working Model of E ² R-F ² N	
Considerations: D_{hm}: Data amount transmitted from human touch detecting sensor node to microcontroller D_{wm}: Data amount transmitted from product weight detecting sensor node to microcontroller D_{md}: Data amount transmitted from microcontroller to mobile device U_{sm}: Data transmission rate from sensor node to microcontroller U_{md}: Data transmission rate from microcontroller to mobile device U_{dm}: Data transmission rate from mobile device to microcontroller	
Input at layer 1: Sensor nodes in trolley, smart phone Output from layer 1: Sensor data, product data, mobile device's ID	
Input at layer 2: Sensor data, product data, mobile device's ID Output from layer 2: Fog device's retail data	
Input at layer 3: Fog device's retail data Output from layer 3: Cloud servers' retail data	
1. Start 2. For 1:N customers 3. Customer enters into the shop with his/her smart phone 4. The customer touches an empty smart trolley and places his/her smart phone into the front space of the empty trolley 5. The sensor S attached with the trolley detects the event human touch and sends a signal to the microcontroller M with the delay calculated as, $L_{hmi} = \frac{D_{hm}}{U_{sm}} \quad (1)$ 6. The microcontroller M sends a message to the smart phone D and the attached bulb 7. Retail app A is opened on the smart phone screen showing an Welcome note and bulb glows green 8. A log in page is opened on the screen and customer is asked to provide ID and password 9. If the customer is a new user, 10. He/she creates new ID and password 11. Else 12. The customer provides his/her ID and password	

13. **End if**
14. **If** the customer successfully log in,
15. The menu list for the product item categories available in shopping centre is opened by the app
16. The user selects item category from the menu
17. The GPS tracker tracks the location of the user and the route towards the selected product category is displayed on the screen
18. Following the route the customer reaches to the product location
19. The user picks the product and puts into the trolley
20. The sensor S attached with the trolley detects an increase in the trolley weight and sends a signal to the microcontroller M with the delay calculated as,

$$L_{wmi} = \frac{D_{wm}}{U_{sm}} \quad (2)$$
21. The microcontroller M sends a signal to the bulb attached with the trolley
22. The microcontroller M sends a message to the smart phone D with the delay calculated as,

$$L_{md} = \frac{D_{md}}{U_{md}} \quad (3)$$
23. A product purchase page is opened by the app A and the bulb glows red
24. The customer is asked to enter the bar code number of the product
25. After correct bar code is entered, a payment page is opened
26. The user makes payment digitally and the smart phone D sends a message to the microcontroller M with the delay calculated as,

$$L_{dm} = \frac{D_{dm}}{U_{dm}} \quad (4)$$
27. The microcontroller M sends a signal to the bulb, which then glows green
28. The product database maintained inside the femtolet F allocated inside the corresponding shopping region is updated
29. A page is opened on the smart phone screen with continue and exit buttons
30. **If** the user clicks on continue button,
31. Repeat step 15 to 29
32. **Else if** the user clicks on exit button,
33. The app A gets closed by showing a Thank you note.
34. **End if**
35. **End if**
36. **End for**
37. The femtolets allocated in the shopping centre send their respective product databases at

- a fixed time interval to the local cloud servers
38. **If** a femtolet F detects that any product quantity has reached to 0,
 39. The femtolet F sends message to the local cloud servers
 40. The local cloud server C sends a message to the mobile device of the product supplier mentioning the required quantity of the product to be delivered
 41. The product supplying agency then takes required initiative to deliver products
 42. **End if**
 43. **If** the admin wishes, the product database is maintained inside the remote cloud servers
 44. **End if**
 45. When any discount or similar offers are launched in the shopping mall, advertisements on the social networking sites about these offers are displayed.
 46. **End**

If we consider N number of customers, then the procedure is performed for all these customers. Thus the complexity of the algorithm will be of $O(N)$. Section 5 discusses in detail the delay and power consumption of the proposed model.

3.3 Security Algorithms Used in Femtolet and Local Cloud Servers

Private and public cryptographic methods are used in femtolet and cloud servers. TABLE 2 presents the cryptographic algorithms used for securing data transmission and data storage in femtolet.

TABLE 2 Cryptographic algorithms used in femtolet

Name of cryptography algorithm	Where to provide security	Advantage
HMAC-SHA	IPSec Tunnel	Used for securing data transmission
Tripple DES-CBC	IPSec Tunnel	
AES-CBC	IPSec Tunnel	
ECC	Femtolet, local cloud servers	Used for securing storage
HIBC	Femtolet, local cloud servers	Used for securing cloud computing services

Femtolet contains a dedicated chip which contains a cryptographic processor like femtocell⁴⁶. The femtolet is connected with the network through Se-GW. The data transmission takes place through a security tunnel. An Internet Protocol Security (IPSec) connection is used^{47,48}. Using a hash function and key, authentication is performed; this is referred as Keyed-Hash Message Authentication Code (HMAC)-Secure Hash Algorithm (SHA). Tripple Data Encryption Standard

(Tripple DES) based Cipher Block Chaining (CBC) and Advanced Data Encryption Standard (AES) based Cipher Block Chaining (CBC) are used⁴⁹.

Among the public key cryptographic algorithms, Elliptic-Curve Cryptography (ECC) is used for securing data storage inside femtolet and cloud servers. In crypto cloud computing Quantum Direct Key is used which is based on private and public key pair⁵⁰. Hierarchical Identity-Based Cryptography (HIBC) can also be used in cloud servers as a public key cryptographic method⁵¹.

3.4 Use of Bitcoin and Blockchain

While making payment digitally bitcoin system is popular nowadays. This is a decentralized digital payment system where the payment making is performed directly without the intervention of an intermediate like central bank. Bitcoin is a cryptocurrency approach. In cryptocurrency encryption is used to control the currency unit generation and verify fund transfer; it operates independently without an intermediate. As we are using femtolet that is connected to the network through Se-GW, a security tunnel is maintained during data transmission. In bitcoin system the network nodes are used to verify the transactions by using cryptography and the records are maintained inside blockchain. Blockchain is a chain of blocks where each block has a hash up to the genesis block of the chain. Using bitcoin system the user can make payment. A secure brokerage model has been discussed for retail banking services in a research work⁵². Secure brokerage model can be incorporated in proposed E²R-F²N while making payment digitally.

3.5 Mathematical Model of E²R-F²N

The mathematical definitions of the components at different layers of E²R-F²N are provided in this section.

3.5.1 Layer 1

Definition 1: Sensor node:

A sensor node is denoted by S and defined as $S = (S_{id}, S_e)$, where S_{id} denotes the unique ID of a sensor node and S_e is the event sensed by the sensor node. The weight detection while an item is put into the trolley, human touch detection when a person takes the trolley etc. are different events sensed by the respective sensor nodes.

Definition 2: Microcontroller:

A microcontroller is denoted by M and defined as $M = (M_{id}, M_e)$, where M_{id} denotes the unique ID of the microcontroller and M_e is the event set detected by the microcontroller from the

connected sensor nodes; this depends on the sensor nodes with which the microcontroller is connected, M_e is denoted by a set $\{S_{e1}, S_{e2}, \dots, S_{en}\}$, where S_{ei} denotes the event sensed by sensor node S_i , where $1 \leq i \leq n$ and n is the number of sensor nodes with which the microcontroller is connected.

Definition 3: Mobile device:

A mobile device is denoted by D and defined as $D = (D_{id}, D_M, A_k, F_{in})$, where D_{id} denotes unique ID of the mobile device, D_M is the message received from microcontroller, A_k is the instance of the retail application executed inside the mobile phone, F_{in} is the message received from the connected fog device femtolet.

Mapping in layer 1:

The mapping from the sensor nodes to the microcontroller is a many-to-one mapping and it is denoted as, $M'(.): S' \rightarrow M$.

Mapping from layer 1 to layer 2:

The mapping from the mobile devices of layer-1 to the fog device femtolet of layer-2 is a many-to-one mapping and it is denoted as, $M'(.): D' \rightarrow F$.

3.5.2 Layer 2

Definition 4: Fog device femtolet:

A fog device is denoted by F and defined as $F = (F_{id}, F_D, F_{sp}, F_c)$, where F_{id} denotes the unique ID of the fog device, F_D is a set denoting the message received from the connected mobile devices given as $\{F_{D1}, F_{D2}, \dots, F_{Dm}\}$, F_{Dj} denotes the message received from mobile device D_j , where $1 \leq j \leq m$ and m is the number of mobile devices with which the femtolet is connected, F_{sp} is the amount of data stored and processed inside the femtolet, and F_c is the message received from the connected local cloud via Se-GW.

Definition 5: Se-GW:

A Se-GW is denoted by SE and defined as $SE = (SE_{id}, SE_F, SE_c)$, where SE_{id} denotes the unique ID of the Se-GW, SE_F is a set denoting the message received from the connected femtolets given as $\{SE_{F1}, SE_{F2}, \dots, SE_{Fq}\}$, SE_{Ft} denotes the message received from a femtolet F_t , where $1 \leq t \leq q$ and q is the number of femtolets with which the Se-GW is connected, SE_c is the message received from the local cloud via HNB-GW.

Definition 6: HNB-GW:

A HNB-GW is denoted by H and defined as $H = (H_{id}, H_{SE}, H_c)$, where H_{id} denotes the unique ID of the HNB-GW, H_{SE} denotes the message received from the connected Se-GW, H_c is the

message received from the local cloud.

Mapping from layer 2 to layer 3:

The mapping from the fog devices of layer-2 to the local cloud of layer-3 is a many-to-one mapping and it is denoted as, $M'(.): F' \rightarrow C$.

3.5.3 Layer 3

Definition 7: Local cloud instance:

A local cloud computing instance is mathematically defined as $C = (C_{id}, C[b])$, where, C_{id} is the distinctive identity of the local cloud component, $C[b]$ is the tuple, defines a non-empty array of size b which stores the processing unit IDs of all the essential local cloud servers.

Definition 8: Remote cloud instance:

A remote cloud computing instance is mathematically defined as $R = (R_{id}, R[v])$, where, R_{id} is the distinctive identity of the remote cloud component, $R[v]$ is the tuple, defines a non-empty array of size v which stores the processing unit IDs of all the essential remote cloud servers.

Mapping in layer 3:

The mapping from the local cloud to remote cloud is a many-to-one mapping and it is denoted as, $M'(.): C' \rightarrow R$.

In the next section we develop an android app for our proposed E^2R-F^2N .

4 PROPOSED ANDROID APP FOR E^2R-F^2N

We design an android app “RetailMyFriend” in this section. A user enters into the shopping mall and takes a smart trolley. Using the android app, the user selects and purchases item. FIGURE 3 shows the designed android app. In FIGURE 3a the app shows welcome note on the screen. FIGURE 3b shows the screen where the user is asked to enter the customer ID and password. If the user is new, he/she clicks on sign up button. Otherwise the user enters customer ID and password. After successful log in the item category list is displayed on the screen as shown in FIGURE 3c. The user selects desired item category and clicks on continue.

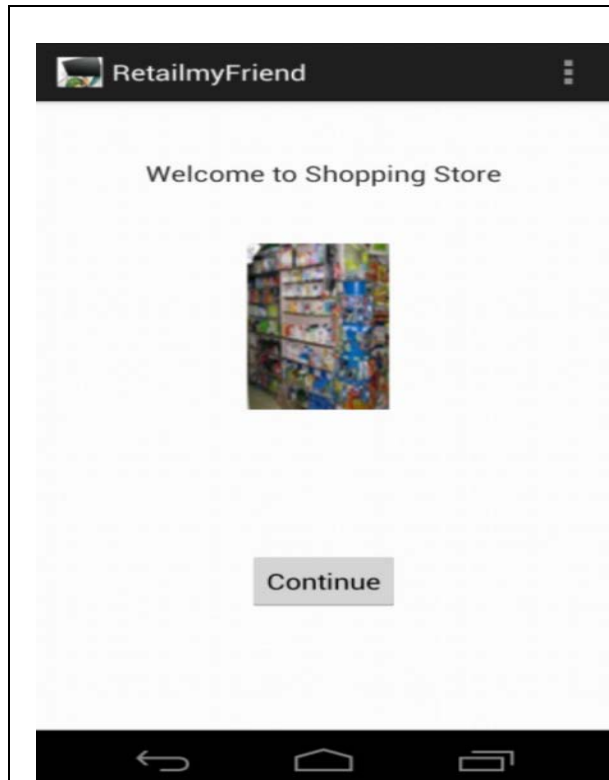


FIGURE 3a. Welcome note is shown on screen

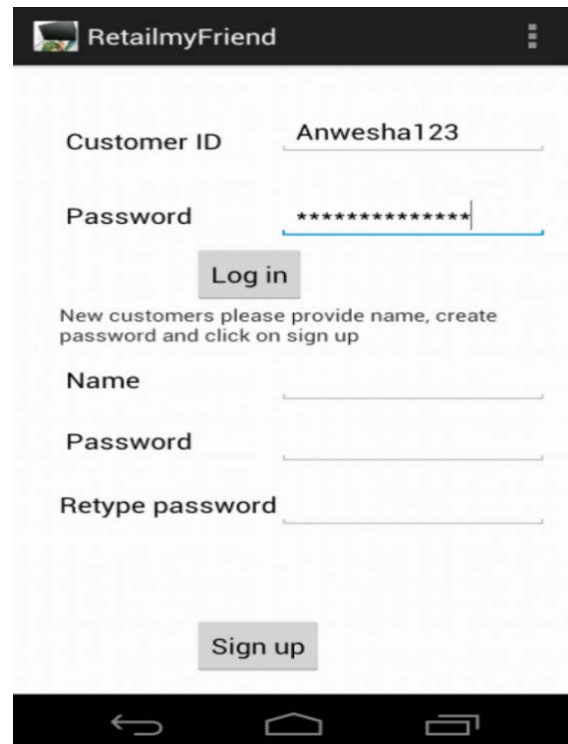


FIGURE 3b. Customer enters ID and password

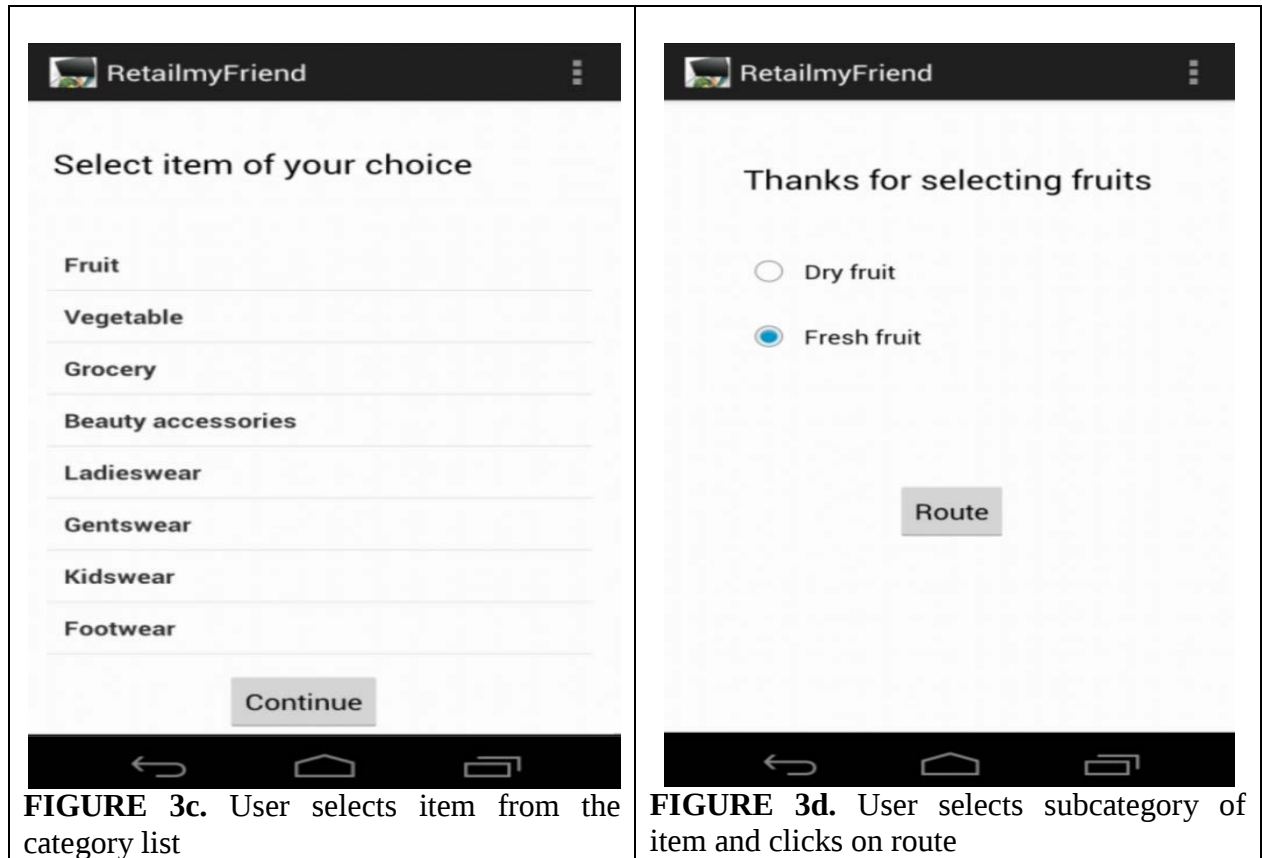


FIGURE 3c. User selects item from the category list

FIGURE 3d. User selects subcategory of item and clicks on route

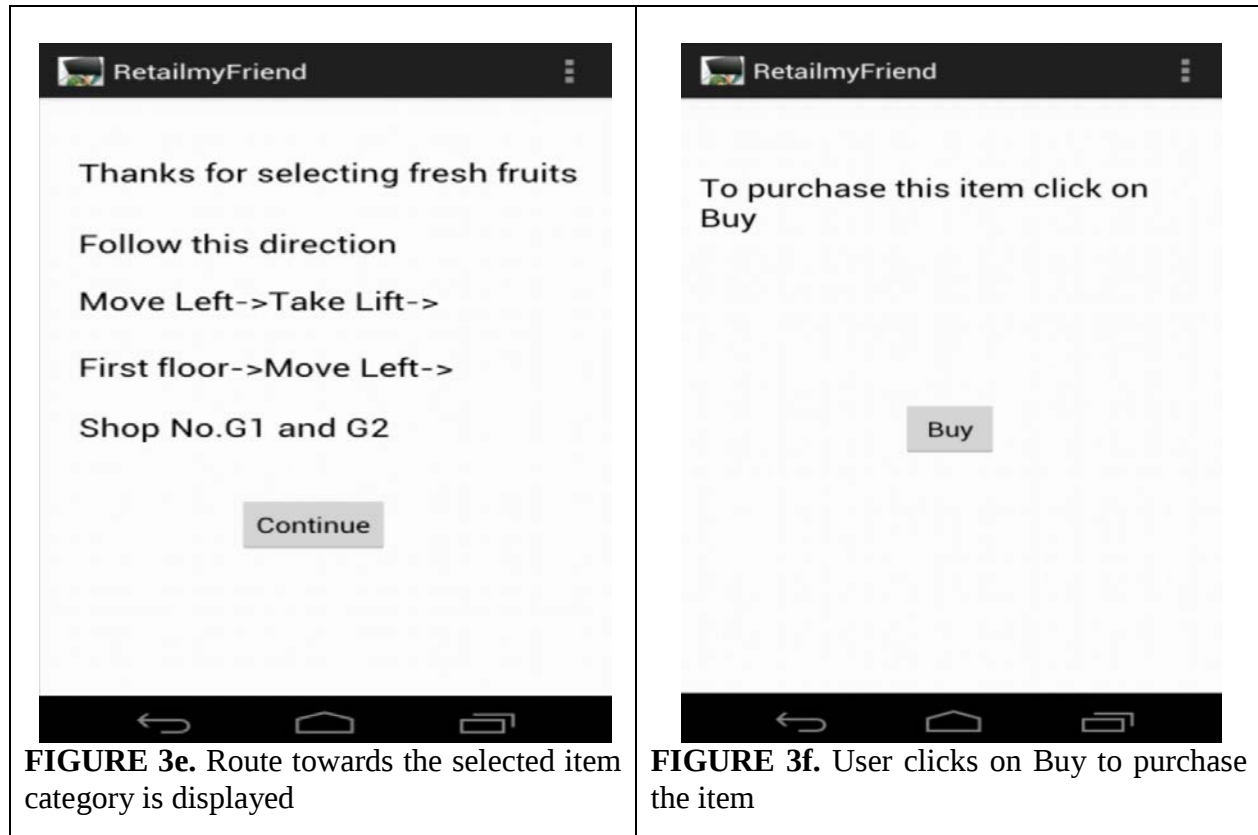


FIGURE 3e. Route towards the selected item category is displayed

FIGURE 3f. User clicks on Buy to purchase the item

The subcategory of item is displayed in the next page; the user selects the subcategory of item he/she wants to buy and clicks on route (see FIGURE 3d). The route towards the selected subcategory of item is displayed on the screen (see FIGURE 3e). Based on customer's location captured by GPS, the route towards the selected item subcategory is displayed on the screen as shown in FIGURE 3e. Following this route user moves towards the item and takes it from the rack. If the user puts the item in the smart trolley, the user is asked to buy the item. If the user wishes to purchase the item, he/she clicks on Buy button as shown in FIGURE 3f. After the user clicks on Buy, the user is asked to enter the bar code. After correct bar code is entered, using digital wallet the customer makes payment. If any offer is going on in the shopping centre for purchase on any product, that advertisement is displayed on the mobile screen.

5 DELAY AND POWER CONSUMPTION IN E^2R-F^2N

The parameters used for calculating power and delay are given in TABLE 3.

TABLE 3 Parameters used in calculating delay and power for E^2R-F^2N

Parameter	Definition
D_{sm}	Amount of data transmission from a sensor node to microcontroller
D_{md}	Amount of data transmission from microcontroller to mobile device
D_{df}	Amount of data transmission from mobile device to femtolet
D_{fc}	Amount of data transmission from femtolet to local cloud
D_{cr}	Amount of data transmission from local cloud to remote cloud
D_{fd}	Amount of data reception by mobile device from femtolet
D_{cf}	Amount of data reception by femtolet from local cloud
D_{rc}	Amount of data reception by local cloud from remote cloud
D_{spf}	Amount of processed and stored data inside femtolet
D_{spc}	Amount of processed and stored data inside local cloud
D_{spr}	Amount of processed and stored data inside remote cloud
U_{sm}	Data amount sent from a sensor node to microcontroller per unit time
U_{md}	Data amount sent from microcontroller to mobile device per unit time
U_{df}	Data amount sent from mobile device to femtolet per unit time
U_{fc}	Data amount sent from the femtolet to local cloud per unit time
U_{cr}	Data amount sent from local cloud to remote cloud per unit time
U_{fd}	Data amount received by mobile device from femtolet per unit time
U_{cf}	Data amount received by femtolet from local cloud per unit time
U_{rc}	Data amount received by local cloud from remote cloud per unit time
p_{sm}	Power in sending unit amount data from a sensor node to microcontroller
p_{md}	Power in sending unit amount data from microcontroller to mobile device
p_{df}	Power in sending unit amount data from mobile device to femtolet
p_{fc}	Power in sending unit amount data from femtolet to local cloud
p_{cr}	Power in sending unit amount data from local cloud to remote cloud
p_{fd}	Power in receiving unit amount data by mobile device from femtolet
p_{cf}	Power in receiving unit amount data by femtolet from local cloud
p_{rc}	Power in receiving unit amount data by local cloud from remote cloud
S_c	Data processing speed of local cloud
S_r	Data processing speed of remote cloud
S_f	Data processing speed of femtolet
S_d	Number of instructions executed by mobile device per unit time
I	Number of instructions executed inside mobile device
p_{ds}	Mobile device's power consumption per unit time to transmit data
p_{dr}	Mobile device's power consumption per unit time to receive data
p_{di}	Mobile device's power consumption per unit time in idle mode
p_{da}	Mobile device's power consumption per unit time in active mode
p_{fa}	Femtolet's power consumption per unit time in active mode
p_c	Local cloud servers' power consumption per unit time

p_r	Remote cloud servers' power consumption per unit time
-------	---

5.1 Delay

The delay for sending data from a sensor node S_i to microcontroller is given by, $L_{smi} = \frac{D_{sm}}{U_{sm}}$.

If n is the number of sensor nodes connected with the microcontroller in a smart trolley and the delays for node 1 to n are $L_{sm1}, L_{sm2}, \dots, L_{smn}$ respectively, the delay for receiving data at microcontroller is given by,

$$L_{sm} = L_{sm1} + L_{sm2} + \dots + L_{smn} = \sum_{i=1}^n L_{smi} \quad (5)$$

The delay for sending data from microcontroller to mobile device is given by,

$$L_{md} = \frac{D_{md}}{U_{md}} \quad (6)$$

The delay for sending data from mobile device to femtolet is given by,

$$L_{df} = \frac{D_{df}}{U_{df}} \quad (7)$$

The retail application execution delay in mobile device is given by,

$$L_d = \frac{I}{S_d} \quad (8)$$

The data processing delay in femtolet is given by,

$$L_f = \frac{D_{spf}}{S_f} \quad (9)$$

The delay for receiving data by mobile device from femtolet is given by,

$$L_{fd} = \frac{D_{fd}}{U_{fd}} \quad (10)$$

Thus the total delay for the customer while using proposed E²R-F²N is given by,

$$L_{srs1} = L_{sm} + L_{md} + L_{df} + L_d + L_f + L_{fd} \quad (11)$$

The delay for data transmission from femtolet to local cloud is given by,

$$L_{fc} = \frac{D_{fc}}{U_{fc}} \quad (12)$$

The delay for data reception by femtolet from local cloud is given by,

$$L_{cf} = \frac{D_{cf}}{U_{cf}} \quad (13)$$

The delay for data transmission from local cloud to remote cloud is given by,

$$L_{cr} = \frac{D_{cr}}{U_{cr}} \quad (14)$$

The delay for data reception by local cloud from remote cloud is given by,

$$L_{rc} = \frac{D_{rc}}{U_{rc}} \quad (15)$$

The data processing delay in local cloud is given by,

$$L_c = \frac{D_{spc}}{S_c} \quad (16)$$

The data processing delay in remote cloud is given by,

$$L_r = \frac{D_{spr}}{S_r} \quad (17)$$

Therefore for a single femtolet the total delay for data processing, data transmission as well as reception from local cloud is given by,

$$L_{totf} = L_f + L_{fc} + L_{cf} \quad (18)$$

For the local cloud the total delay for data processing, data transmission as well as reception from remote cloud is given by,

$$L_{totc} = L_c + L_{cr} + L_{rc} \quad (19)$$

5.2 Power consumption

The power consumed for sending data from sensor nodes to microcontroller is given by,

$$P_{sm} = \sum_n D_{sm} \cdot p_{sm} \quad (20)$$

where n is the number of sensor nodes connected with the microcontroller in a smart trolley.

The power consumed for sending data from microcontroller to mobile device is given by,

$$P_{md} = D_{md} \cdot p_{md} \quad (21)$$

The power consumed for sending data from mobile device to femtolet is given by,

$$P_{df} = D_{df} \cdot p_{df} \quad (22)$$

The power consumption for retail application execution in mobile device is given by,

$$P_d = L_d \cdot p_{da} \quad (23)$$

The power consumption for data processing in femtolet is given by,

$$P_f = L_f \cdot p_{fa} \quad (24)$$

The power consumed for receiving data by mobile device from femtolet is given by,

$$P_{fd} = D_{fd} \cdot p_{fd} \quad (25)$$

Thus the total power consumed for the customer while using proposed E²R-F²N is given by,

$$P_{srs1} = P_{sm} + P_{md} + P_{df} + P_d + P_f + P_{fd} \quad (26)$$

The power consumed for data transmission from femtolet to local cloud is given by,

$$P_{fc} = D_{fc} \cdot p_{fc} \quad (27)$$

The power consumed for data reception by femtolet from local cloud is given by,

$$P_{cf} = D_{cf} \cdot p_{cf} \quad (28)$$

The power consumed for data transmission from local cloud to remote cloud is given by,

$$P_{cr} = D_{cr} \cdot p_{cr} \quad (29)$$

The power consumed for data reception by local cloud from remote cloud is given by,

$$P_{rc} = D_{rc} \cdot p_{rc} \quad (30)$$

The power consumption for data processing in local cloud is given by,

$$P_c = L_c \cdot p_c \quad (31)$$

The power consumption for data processing in remote cloud is given by,

$$P_r = L_r \cdot p_r \quad (32)$$

Therefore for a single femtolet the total power consumed for data processing, data transmission as well as reception from local cloud is given by,

$$P_{totf} = P_f + P_{fc} + P_{cf} \quad (33)$$

For the local cloud the total power consumed for data processing, data transmission as well as reception from remote cloud is given by,

$$P_{totc} = P_c + P_{cr} + P_{rc} \quad (34)$$

The mobile device i.e. smart phone's power consumption for data transmission, reception and application execution is given by,

$$P_{told} = p_{da} \cdot L_d + p_{dr} \cdot L_{md} + p_{ds} \cdot L_{df} + p_{dr} \cdot L_{fd} + p_{di} \cdot L_{sm} \quad (35)$$

In the next section the delay and power consumption in E²R-F²N will be determined and compared with cloud servers based retail systems.

6 PERFORMANCE EVALUATION

We evaluate performance of our system through multiple approaches: analytical, simulation, and experimentation as discussed in this section.

6.1 Analytical Evaluation

In this section, we have calculated the delay and power consumption in proposed E²R-F²N and compared the results with local cloud server and remote cloud server based retail systems. These results are obtained based on the simulations performed in MATLAB R2015a. The data amount stored and accessed for the retail system, inside femtolet and local cloud servers are assumed as 50-300 GB and 500-3000 GB respectively. The data amount transmitted from a mobile device to

femtolet is assumed as 0.5-3 MB and this is the data amount accessed for a user, assumed in simulation. While a user selects and purchases items using proposed E^2R-F^2N , the delay consumed is calculated and presented in FIGURE 4. The delay is measured in second (s). The results are compared with the retail systems where instead of femtolet, Wi-Fi access point is used and the data storage and access are performed inside the local or remote cloud servers³⁶. During selection and purchase of items using proposed E^2R-F^2N , the mobile device i.e. smart phone's power consumption is calculated. The obtained results are presented in FIGURE 5 along with the power consumption of mobile device in case of local or remote cloud servers based retail systems³⁶, where instead of femtolet, Wi-Fi access point is used and the data storage and access are performed inside the local or remote cloud servers. The power is measured in Watt (W). The results presented in FIGURE 4 illustrate that the proposed E^2R-F^2N reduces the delay by approximately 90% and 95% respectively than local and remote cloud servers based retail systems³⁶.

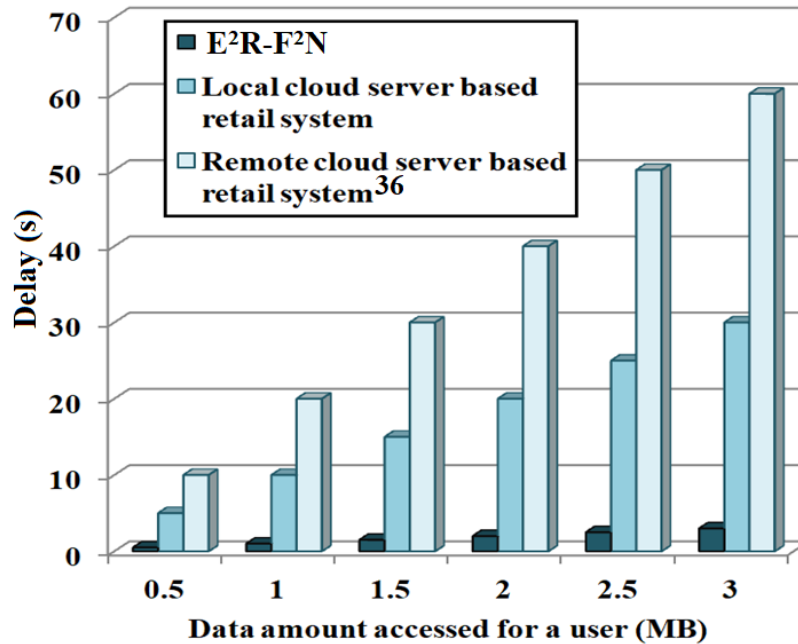


FIGURE 4. Delay for a user in proposed E^2R-F^2N and existing cloud servers based retail systems

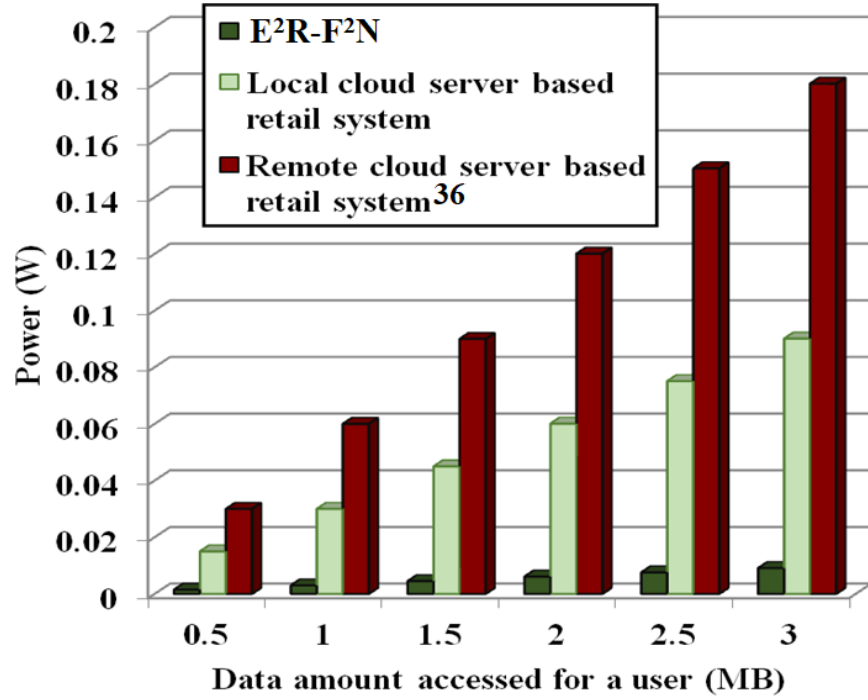


FIGURE 5. Smart phone's power consumption in proposed E²R-F²N and existing cloud servers based retail systems

FIGURE 5 demonstrates that the proposed E²R-F²N reduces the mobile device's power consumption by approximately 89% and 94% respectively than local and remote cloud servers based retail systems³⁶. The results demonstrate that the proposed E²R-F²N is a green retail system. By reducing delay the user's experience is improved. As the power and delay both are reduced, the QoS of the retail system is enhanced.

6.2 Simulation using Qualnet 7

In Qualnet7 we have created the E²R-F²N scenario. Four sensors nodes are considered which are attached with the trolley and these sensor nodes are connected with the microcontroller attached with the trolley. The microcontroller is connected with the mobile phone of the user. The mobile phone is connected with femtolet. Based on purchase, the product database is updated inside the femtolet. The femtolet sends the updated product database to the local cloud server twice a day. The local cloud is connected with the remote cloud servers. The parameters of simulation are given in TABLE 4 and the simulation scenario is presented in FIGURE 6. In FIGURE 6 sensor nodes (1, 2, 3, 9) are connected with the microcontroller (node 4). Node 4 is connected with the mobile device (node 5) of the user. The mobile device is connected with the femtolet (node 6). The femtolet is a base station with storage and computation ability; it works as the fog device in

E^2R-F^2N . The femtolet holds the databases of the products present under its coverage. The femtolet is connected with the local cloud (node 7). The local cloud is connected with the remote cloud (node 8).

TABLE 4 Simulation parameters

Parameter	Value
Radio type	802.15.4 radio, 802.11b radio
Packet reception model	PHY 802.15.4 reception model, PHY 802.11b reception model
Energy model for sensor nodes and microcontroller	Mica-motes
MAC protocol	802.15.4, 802.11
Network protocol	IPV4
Routing protocol	AODV
Simulation time	300 sec

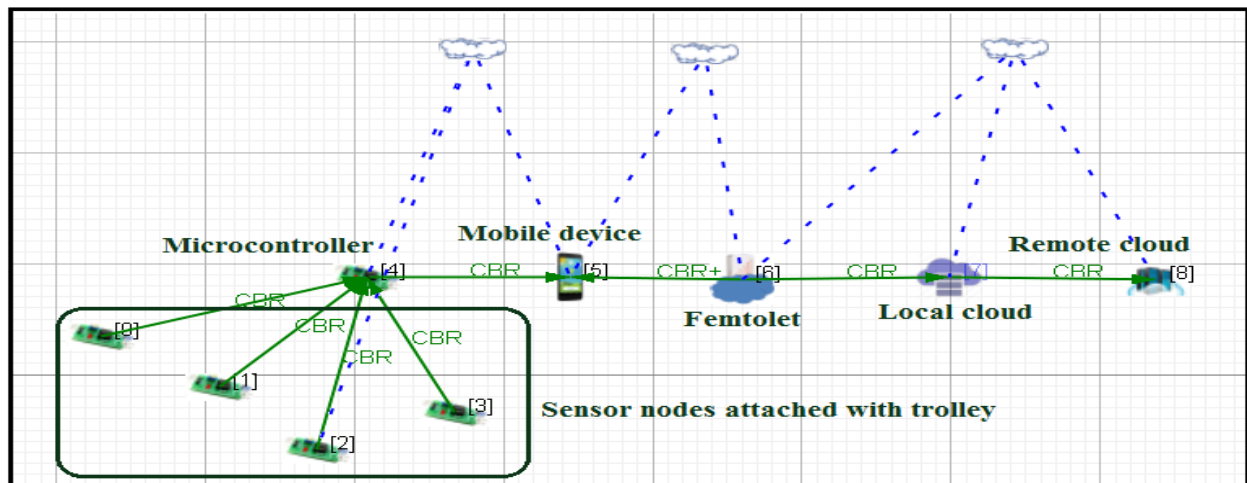


FIGURE 6a. E^2R-F^2N scenario created in Qualnet7

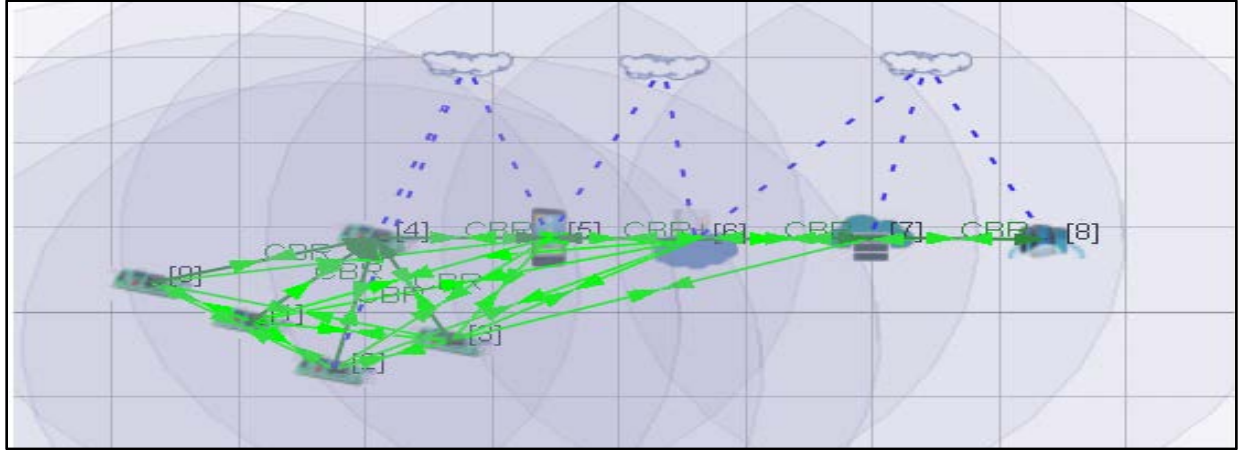


FIGURE 6b. Simulation scenario during execution

6.2.1 Carried load

FIGURE 7 presents the carried load by the nodes in proposed E^2R-F^2N with respect to the amount of transmitted data between two consecutive nodes. This is observed from the FIGURE that the carried load is <1700000 bits/s approximately for 100-1000 MB data transmission between two consecutive nodes.

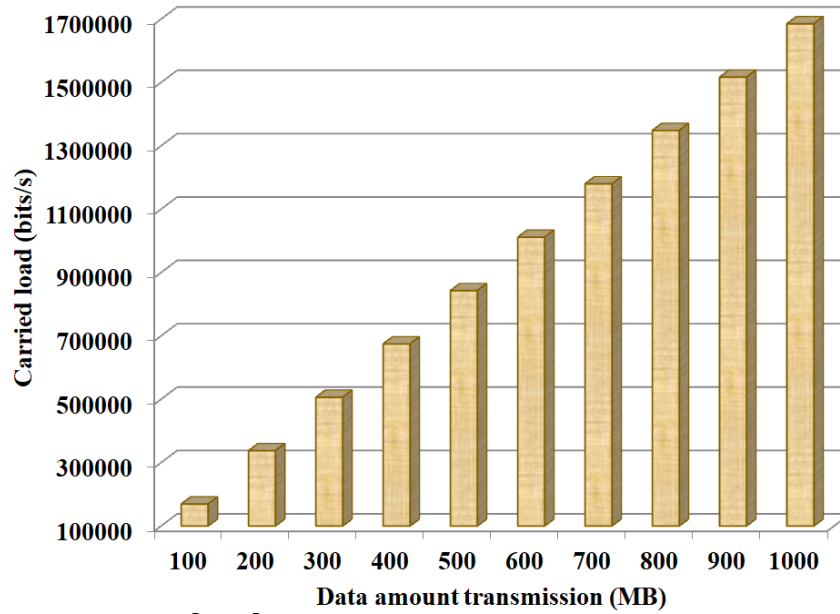


FIGURE 7. Carried load in E^2R-F^2N

6.2.2 Unicast received throughput

FIGURE 8 presents the unicast received throughput of the nodes in proposed E^2R-F^2N with respect to the amount of transmitted data between two consecutive nodes.

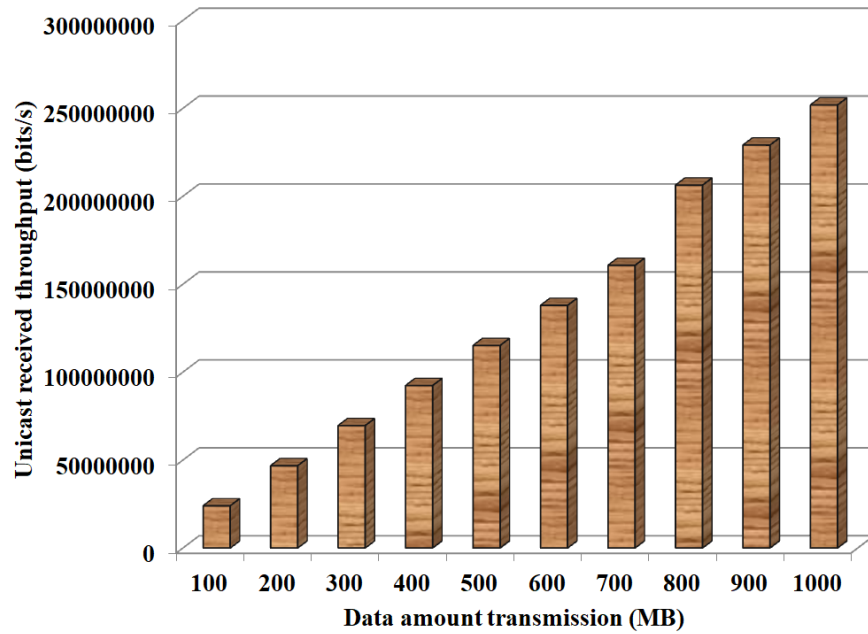


FIGURE 8. Unicast received throughput in E^2R-F^2N

This is observed from the FIGURE that the unicast received throughput is <3000000000 bits/s approximately for 100-1000 MB data transmission between two consecutive nodes.

6.2.3 Average delay

FIGURE 9 presents the average delays of proposed E^2R-F^2N , local and remote cloud servers based retail systems, with respect to the amount of transmitted data between two consecutive nodes.

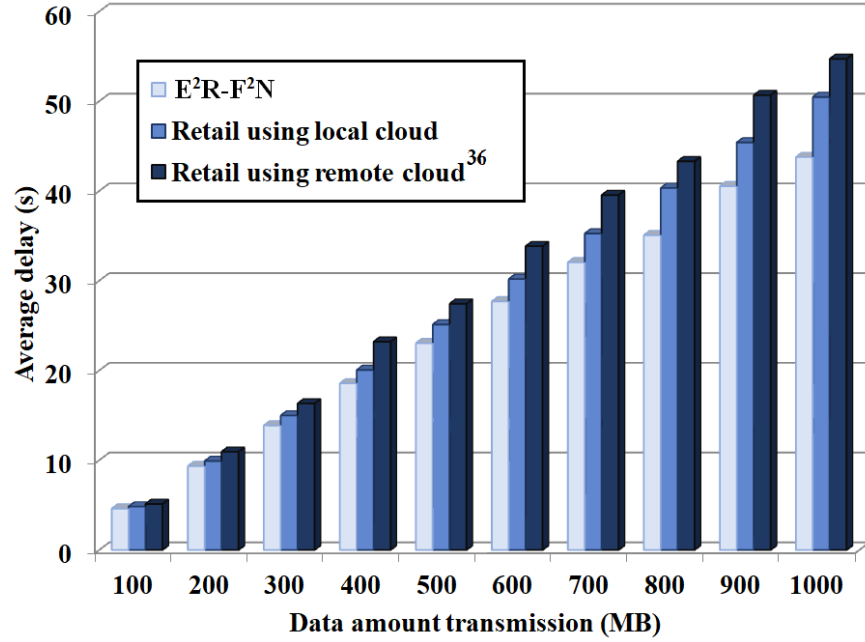


FIGURE 9. Average delay in E²R-F²N, local and remote cloud based retail systems

Delay refers to the time between sending a packet by the sender node and receiving the same packet by the receiver node. The delay is measured in second (s). This is observed from the FIGURE that the average delays for E²R-F²N, local and remote cloud servers based retail systems are respectively <50 s, ≤50 s and <60 s approximately for 100-1000 MB data transmission between two consecutive nodes. The simulation results demonstrate that E²R-F²N reduces the average delay by 4-12% and 10-20% approximately than the local and remote cloud based retail systems³⁶ respectively.

6.2.4 Average jitter

FIGURE 10 presents the average jitters of proposed E²R-F²N, local and remote cloud servers based retail systems, with respect to the amount of transmitted data between two consecutive nodes. Jitter refers to the delay between receiving two consecutive packets by a node. This is observed from the FIGURE that the average jitters for E²R-F²N, local and remote cloud servers based retail system are respectively <7 s, ≤8 s and <9 s approximately for 100-1000 MB data transmission between two consecutive nodes. The simulation results demonstrate that E²R-F²N reduces the average jitter by 3-21% and 8-25% approximately than the local and remote cloud based retail systems³⁶ respectively.

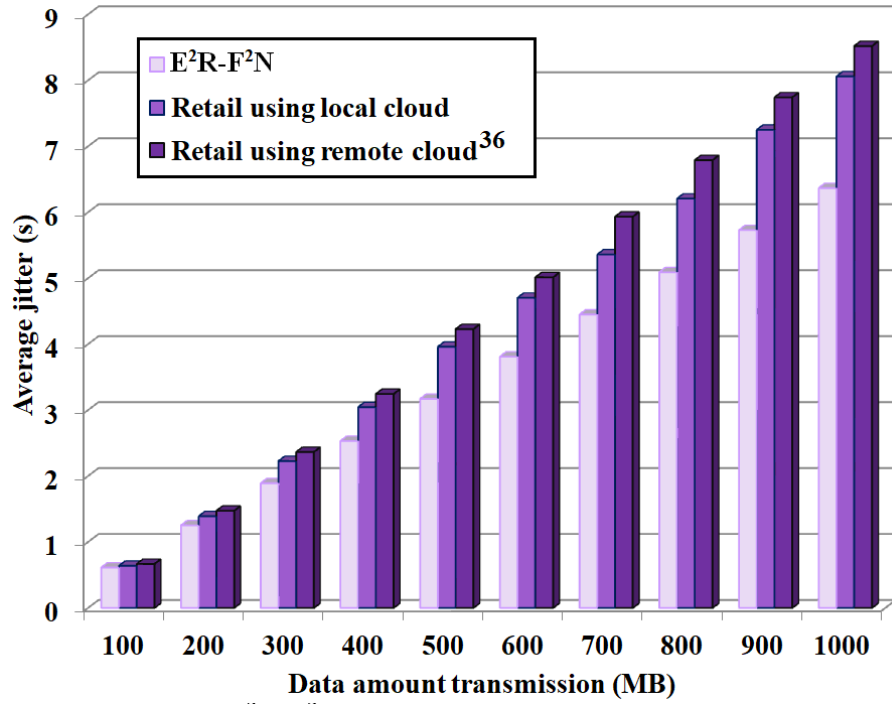


FIGURE 10. Average jitter in E²R-F²N, local and remote cloud based retail systems

6.2.5 Energy consumption

FIGURE 11 presents the energy consumed by proposed E²R-F²N, local and remote cloud servers based retail systems, with respect to the amount of transmitted data between two consecutive nodes.

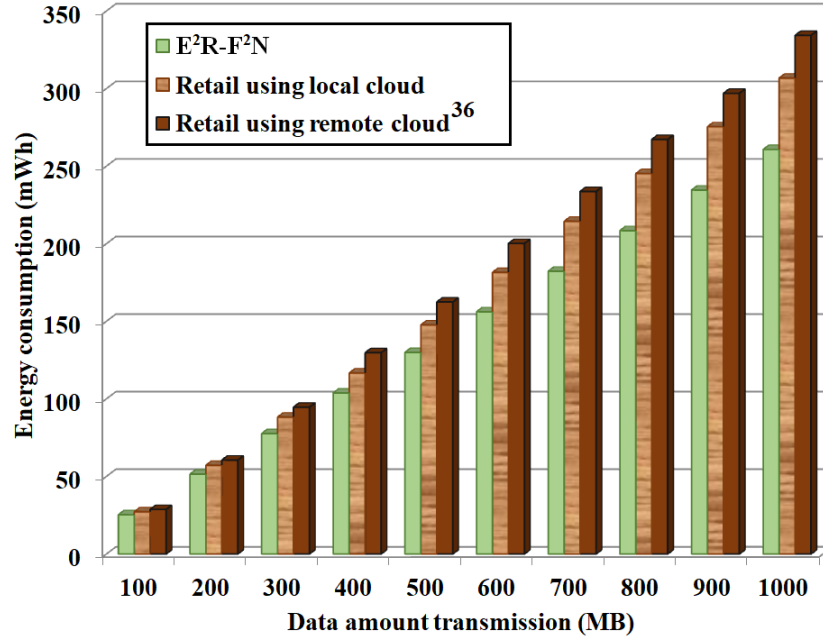


FIGURE 11. Energy consumption in E²R-F²N, local and remote cloud based retail systems

This is observed from the FIGURE that the energy consumption of E²R-F²N, local and remote cloud servers based retail systems are respectively <300 mWh, ≤300 mWh and <350 mWh approximately for 100-1000 MB data transmission between two consecutive nodes. The energy consumption of the nodes in transmit and receive modes are summed up to calculate the energy consumption. The simulation results demonstrate that E²R-F²N reduces the energy consumption by 6-15% and 12-22% approximately than the local and remote cloud based retail systems³⁶ respectively.

From the simulations results we observe that E²R-F²N reduces the average delay and jitter than the local and remote cloud server based retail systems. As the delay and jitter are reduced, the QoS of the system is enhanced. According to the simulation results the energy consumption is also lower in E²R-F²N than the local and remote cloud based retail systems. Hence we can refer E²R-F²N as an energy-efficient i.e. green retail system.

6.3 Experimental Analysis of Product Database Update at Fog device

For experimental purpose we consider product database of ladies beauty accessory lipstick maintained inside a shopping centre. The configurations of the fog device, local cloud servers and smart phones used in the experiment are noted in TABLE 5.

TABLE 5 Configurations of smart phones, fog device and local cloud servers

Equipment	RAM	HDD	Processor	Operating
-----------	-----	-----	-----------	-----------

				System
Oppo A57	3 GB	32 GB	QualcommMSM8940 octa-core	Android V 6.0.1
Samsung Galaxy On8	3 GB	16 GB	1.6 GHz octa-core	Android V 6.0
Samsung Galaxy J2	1 GB	8 GB	1.3 GHz quad-core	Android 5.1.1
Fog device	16 GB	2 TB	Intel(R) Xeon(R) CPU ES-2667 0 @ 2.90 GHz	CentOS
Local cloud server 1	16 GB	1 TB	Intel(R) Xeon(R) CPU ES-2667 0 @ 2.90 GHz	CentOS
Local cloud server 2	16 GB	2 TB	Intel(R) Xeon(R) CPU ES-2667 0 @ 2.90 GHz	CentOS

We consider product database of ladies beauty accessory lipstick maintained inside a shopping centre. First table (Lipstick) contains the product_id, product_name, product_company, product_qty and product_price. The data of lipstick of different companies are maintained. The second table (Supplier) contains the product_company as a reference to product_company of first table, supplier_name and supplier_ph. When a product quantity reaches to 0, the supplier is informed. The lipstick database is maintained by fog device1. When a lipstick is purchased by a customer, the first table is updated. If a product quantity reaches to 0, i.e. if product_qty=0, then the second table is accessed. From the second table the supplier mobile number is obtained from the field supplier_ph. Fog device sends a message to the local cloud servers along with product_id, product_company, supplier_name and supplier_ph informing the product quantity is 0. From the local cloud a message is sent to the supplier's mobile number.

TABLE 6a, 6b and 6c shows the first table at 10:30 am on 24th, 25th and 26th October, 2018 respectively.

TABLE 6a First TABLE at 10:30 am on 24/10/2018

product_id	product_name	product_company	product_qty	product_price
LKL101	Lipstick_Violet_Lak	Lak_C	30	250.00
LKL102	Lipstick_Red_Lak	Lak_C	40	220.00
LKL103	Lipstick_Orange_Lak	Lak_C	35	220.00
LKL104	Lipstick_Black_Lak	Lak_C	20	300.00
LKL105	Lipstick_Pink_Lak	Lak_C	35	200.00
LKL106	Lipstick_Brown_Lak	Lak_C	20	200.00
.....				
.....				
ELL10001	Lipstick_Violet_EI18	EI18	25	350.00
ELL10002	Lipstick_Red_EI18	EI18	50	300.00
ELL10003	Lipstick_Brown_EI18	EI18	50	320.00

TABLE 6b First TABLE at 10:30 am on 25/10/2018

product_id	product_name	product_company	product_qty	product_price
LKL101	Lipstick_Violet_Lak	Lak_C	30	250.00
LKL102	Lipstick_Red_Lak	Lak_C	30	220.00
LKL103	Lipstick_Orange_Lak	Lak_C	35	220.00
LKL104	Lipstick_Black_Lak	Lak_C	20	300.00
LKL105	Lipstick_Pink_Lak	Lak_C	35	200.00
LKL106	Lipstick_Brown_Lak	Lak_C	10	200.00
.....				
.....				
ELL10001	Lipstick_Violet_EI18	EI18	25	350.00
ELL10002	Lipstick_Red_EI18	EI18	45	300.00
ELL10003	Lipstick_Brown_EI18	EI18	45	320.00

TABLE 6c First TABLE at 10:30 am on 26/10/2018

product_id	product_name	product_company	product_qty	product_price
LKL101	Lipstick_Violet_Lak	Lak_C	20	250.00
LKL102	Lipstick_Red_Lak	Lak_C	30	220.00
LKL103	Lipstick_Orange_Lak	Lak_C	30	220.00
LKL104	Lipstick_Black_Lak	Lak_C	20	300.00
LKL105	Lipstick_Pink_Lak	Lak_C	35	200.00
LKL106	Lipstick_Brown_Lak	Lak_C	0	200.00
.....				
.....				
ELL10001	Lipstick_Violet_EI18	EI18	25	350.00
ELL10002	Lipstick_Red_EI18	EI18	40	300.00
ELL10003	Lipstick_Brown_EI18	EI18	35	320.00

On 26/10/2018, the quantity of product 'LKL106' reaches to 0 (see TABLE 6c); the fog device accesses second table (see TABLE 7) and obtains the supplier's mobile number from the field supplier_ph.

TABLE 7 Second TABLE at 10:30 am on 26/10/2018

product_company	supplier_name	supplier_ph
Lak_C	Erinasupply	97#####
EI18	Beautyven	98#####
Oriflm	Femicraz	98#####
MACL	Queensup	97#####
.....		
.....		
Riml	Rimsup	99#####
Soml	Somsup	98#####

The fog device sends a message to the local cloud servers along with product_id (LKL106), product_company (Lak_C), supplier_name (Erinasupply) and supplier_ph (97#####) informing the product quantity is 0.

The delay and power consumptions in accessing these two tables based on the number of customers purchasing the products are provided in TABLE 8. The results are compared with the local and remote cloud server based retail systems.

TABLE 8a Delay in accessing Lipstick in E^2R-F^2N , local and remote cloud servers based retail systems

Number of customers purchasing products	Delay (ms)			Reduction in delay (approx.) using E^2R-F^2N than	
	Local cloud based retail system	Remote cloud based retail system	Proposed E^2R-F^2N	Local cloud based retail system	Remote cloud based retail system
500	652	744	497	23.77%	33.19%
1000	960	1099	612	36.25%	44.31%
1500	1164	1436	660	43.29%	54.04%
2000	1385	1756	736	46.86%	58.09%
2500	1682	2066	782	53.51%	62.15%

TABLE 8b Power consumption in accessing Lipstick in E^2R-F^2N , local and remote cloud servers based retail systems

Number of customers purchasing products	Power consumption (W)			Reduction in power (approx.) using E^2R-F^2N than	
	Local cloud based retail system	Remote cloud based retail system	Proposed E^2R-F^2N	Local cloud based retail system	Remote cloud based retail system
500	0.159	0.182	0.122	23.27%	32.97%
1000	0.235	0.269	0.149	36.59%	44.61%
1500	0.284	0.351	0.161	43.31%	54.13%
2000	0.339	0.429	0.181	46.61%	57.81%
2500	0.411	0.505	0.192	53.28%	61.98%

From the experimental results presented in TABLE 8, we observe that the proposed retail system reduces the delay and power by approximately 23.77-53.51% and 23.27%-53.28% respectively than the local cloud based retail system. This is also observed from TABLE 8 that proposed E^2R-F^2N reduces the delay and power by approximately 33.19-62.15% and 32.97%-61.98% respectively than the remote cloud based retail system. Thus we observe the proposed retail system reduces delay and power by approximately 23-62% and 23-61% respectively than the existing systems. In E^2R-F^2N the fog device maintains the product database of the respective region in which the fog device is deployed. As a result the delay in accessing the product database is reduced, which in turn decreases the power consumption than the local and remote

cloud based retail systems. As the delay and power are reduced, the QoS of the system is enhanced.

7 FUTURE RESEARCH DIRECTIONS

Challenge 1: Online shopping using femtolet

Nowadays, huge number of people like to purchase products online. Generally there are websites for online product purchase. As E^2R-F^2N is designed for shopping centres, the users can purchase product while visiting the mall. If the shopping centre provides an option for purchasing online the products of that shopping mall, the website of the shopping mall has to maintain an online shopping cart system and secure payment mechanism. The user if accesses the Internet service through femtolet, the data transmission and reception takes place through security tunnel. The users residing home can purchase the shopping mall's products online residing home, by accessing Internet through femtolet. To offer online purchase of the products of the shopping centre the product databases have to be maintained inside the remote cloud servers. The security in storage and access to product database will be crucial factors in that case.

Challenge 2: Augmented reality in E^2R-F^2N

Augmented Reality (AR) provides a virtual environment to the users through which the users observe the real word with virtual objects^{36,53}. Using AR a user can work with real 3D objects with the information received visually from a mobile device. In E^2R-F^2N if AR is used, the user can view the products in the shopping centre using his/her mobile device. This can help the user to track the product he/she wants to purchase. For physically disabled users an AR based shopping has been proposed in a research work³⁶. If F^2N is integrated with AR based retailing energy-efficiency can be achieved.

Challenge 3: Product location tracking using deep learning

In our system based on user location the route towards the selected product category is displayed on the smart phone located in the trolley to guide the user. But it may happen that under same category of products the user wishes to select a particular item, for example, while a user selects fresh fruits, different fruits are there. Not only that under a specific fruit category, user may like

to select a particular one. In such a case the system has to be made more user friendly. For product location tracking based on user's gesture, deep learning⁵⁴ can be employed in E²R-F²N.

Challenge 4: Dedoop based energy efficient femtolet for smart retail

Deduplication based hadoop is called Dedoop⁵⁵, it is used to handle big data⁵⁶ in retail chain. As the shopping mall contains huge amount of data inside the femtolets, Dedoop based femtolet has to be developed to remove deduplication problem in next generation retail system. If online retailing is provided, then remote cloud servers also will contain big data for the shopping centre. Dedoop for online retailing to handle huge data is a promising future scope.

Challenge 5: Light Fidelity (LiFi) based energy harvesting IoT using F²N

In LiFi based Retail it is necessary to decrease the overall energy consumption of the IoT nodes⁵⁷. An additional source of energy has become essential for achieving. Crisis of the radio frequency (RF) spectrum, light LiFi offers key benefits. Energy Harvesting Retail (EHR) model for future hybrid LiFi/Femtolet based Fog network may open a new horizon. EHR is capable of high speed transmission by harvesting energy. Multi-device transmission is synchronized by multicoloured LEDs.

Challenge 6: Software defined femtolet based block chain cloud architecture for energy efficient retail

Software defined networking (SDN) offers network management in an easy manner and programmatically efficient network configuration⁵⁸. In SDN the control plane is separated from the forwarding plane. If SDN is integrated with E²R-F²N, the system management can be performed more efficiently. Block chain-cloud architecture using SDN and femtolet as controller of fog nodes at the edge of the network is a challenging research scope of E²R-F²N.

Challenge 7: Privacy preservation in energy efficient retail system

In E²R-F²N the user himself/herself selects and purchases products with the help of smart trolley. The payment is also performed digitally. Therefore privacy preservation is an important factor in E²R-F²N, especially if online retailing is provided.

Challenge 8: Energy-efficient priority retailing

Different users visit shopping centre and purchase products. If the quantity of a product is less than its requirement, then priority has to be assigned to the customers. The priority can be on first come first serve basis or based on how frequently the users visit the shopping mall. The

users who visit the shopping mall frequently can be provided various offers regarding product purchase. Therefore classification of the prioritized and non-prioritized customers is another future scope of E²R-F²N.

Challenge 9: Geo-spatial information analysis for customer demand prediction

Different geographical regions have different types of customers having various types of requirements. Analysing the product database of different shopping centres of different regions the customer demand of different area can be predicted. In this case mapping between the geo-spatial data^{59,60} and product purchase data will be performed to analyse customer demand. The customer demand based product storage and management by the shopping centre based on geo-spatial information is also a challenging research scope.

Challenge 10: Performance and resource-aware orchestration in retailing

Resource allocation in latency and energy optimized way is a vital factor in IoT based on fog computing and mobile cloud computing^{61,62}. Resource allocation and service function chaining (SFC) are demanding research scopes in IoT⁶³. SFC orchestration in E²R-F²N is an interesting research domain, especially if online retailing is provided.

Challenge 11: Commitment and customer loyalty in E²R-F²N

Customer loyalty and commitment are important for commercial organizations⁶⁴. E²R-F²N is a commercial model for purchasing products in a shopping mall. Security and privacy while purchasing products through digital wallet, ease of providing service while guiding user towards the product location through Android app, are important factors for customer satisfaction. Hence for enhancing customer satisfaction, development of more user friendly application which will consider not only GPS but also users' gesture, as well as more secure environment especially in online retailing are vital research areas of E²R-F²N.

8 SUMMARY AND CONCLUSIONS

Smart green retail system is an interesting domain of research. This paper introduces E²R-F²N as a retail system using femtolet based fog network, where in a shopping mall the customer selects and purchases products using a smart trolley. This trolley guides the user towards the location of the selected product category. Sensor nodes are attached with the smart trolley to track the status of items put in the trolley. These sensors are connected with the microcontroller that sends information to the mobile device according to the items put into and picked from the trolley.

Using digital wallet the user makes payment through the mobile device placed in the trolley. Femtolet is used as a fog device, which connects the user with the network. The femtolets in the shopping mall store the product data. The femtolets are connected with local cloud servers, which act as data repository for the shopping mall. The mathematical model of E^2R-F^2N is proposed along with power and delay calculation. The simulation results depict that E^2R-F^2N reduces power and delay by approximately 89% and 90% than the local cloud servers based retail system. The proposed system is simulated in Qualnet 7. The average delay, average jitter, energy consumption, carried load and unicast received throughput of the system are determined. An android app for E^2R-F^2N is developed. Experimental results demonstrate that the proposed fog based retailing reduces delay and power by approximately 23-62% and 23-61% respectively than the cloud servers based system. Finally the future research challenges of E^2R-F^2N are highlighted in this paper.

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