A novel approach to aware slum dwellers during fire breakthrough using D2D communication

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Abstract— People living in slums are severely affected in case of any disaster such as fire or earthquake due to the unawareness of the situation and difficulties associated with rescue operations. Since disaster preparedness and responses are always better than recovery, our goal is to aware habitats for faster response during the disaster occurrence such as fire breakthrough. Conventional fire alarm systems comprising of fire sensors and smart phones offers fire alarm generation for the dwellers and quick communication to the rescue authorities. In addition to the existing system, we propose to aware the dwellers of the slum during fire occurrence not only by starting the siren but also by transmitting fire alarm to their smart phones to aware them; this task will be performed by 4G central public safety smart phone to establish device to device communication with the nearby habitat's smart phone and repeat this action to ripple the alert signal to other habitats; so the nearby dwellers will be notified instantly. Then it will pass the information to the passerby to spread the news and to the responsible authorities for rescue operation. Cost effective analysis and the simulations showed that minimal cost and time is required for the fire alarm generation and propagation compared to the safety of valuable human live.

Index Terms— D2D communication, fire-alarm, Fire breakout, LTE network, Public Safety UE, Proximity service, Slum.

1 Background Stdy: LTE Advanced

A. LTE : LTE stands for Long Term Evolution and it was started as a project in 2004 by telecommunication body known as the Third Generation Partnership Project (3GPP). The main goal of LTE is to provide a high data rate, low latency and packet optimization [1]. LTE also supports voice and SMS text messaging using existing networks. We choose LTE over GSM because it offers D2D communication which decreases the traffic communications while sending data, allows more users to use the same frequency in a cell and offers faster data rate transfer system. Same time its network architecture has been designed with the goal to support packet-switched traffic with seamless mobility and great quality of service.

B. D2D: 4G LTE Advanced device to device communication is for high data rate local direct communications using LTE devices within a small area.LTE D2D communications is a peer to peer link which does not use the cellular network infrastructure, but enables LTE based devices to communicate directly with one another when they are in close proximity [2][3]. One of the particular applications where LTE device to device communication can be used is for the emergency services. LTE device to device communication is also being investigated for applications where peer discovery is required for commercial applications in the presence of network support. Since the smart phones available for commercial use are capable to operate under 4G networks such as LTE networks, it is expected that the proximity services to establish device to device communication will be readily available very soon.

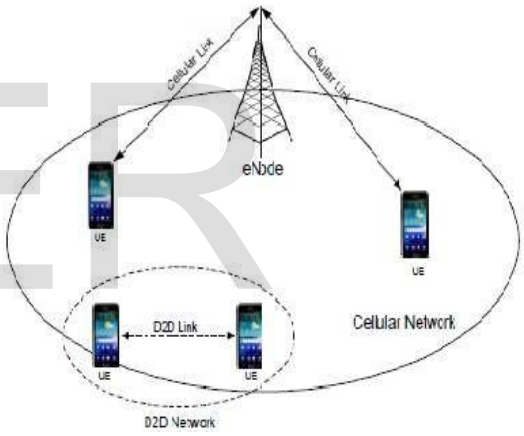

Fig 1. LTE D2D concept

C. Recent Fire alarm systems: Fire breakthrough has been a common disaster either natural or man- made which causes severe damage to environment and live. Many inventions and developments are achieved for fire detection using smoke sensor, heat sensor, fire sensor etc and various fire control mechanisms have been implemented to prevent fire or to response faster during fire breakthrough. Fire alarm control panel is a key equipment and works as a brain for automatic detection system receiving the fire information from the fire detectors and sensors and sending and notifying the information to the fire officers and to the public. Fire alarm control panel can be divided by conventional-type (P-type), addressable type (R-type) and M-type depending on the signal process and location of the equipment and by GP-type, GR-type and hybrid-type depending on the usage. Smart phones are integrated now-a-days with the fire alarm system to send text messages to the fire fighters or monitors. Smart phone applications linked with fire alarm control panel in automatic fire detection system have been developed for monitoring the fire situations in fire control mechanism such as situ including occurrence of

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fires, fire control related equipment, short circuit of the fire detectors, and status of the control panel. As a result, the fire related information in situ can be monitored by the fire officers anywhere and anytime [5]. In large public areas, such as building, school campus, fire alarm system implemented can be monitored by the security personnel. Internet of Things (IOT) is also proposed for fire alarm generation [6]. Smart home plans are also integrating smart phones in the fire alarm systems for prevention and also to inform the owner of the house for safety issues.

2 Case Study: Fire Break Out in Bangladesh

In many under developed countries, most of the citizens live under poverty level and are deprived from fundamental constitutional rights such as food, shelter, education etc. Low income people in large number are forced to live inhumanly in slums or highly populated area with high risk of health and safety issues. Houses are often build too close with very narrow passage way through them and are very crowded. Like many other Asian countries, Bangladesh is a highly populated country with many people living under the poverty level. Dhaka, the capital city of Bangladesh, is one of the most crowded cities around the world.

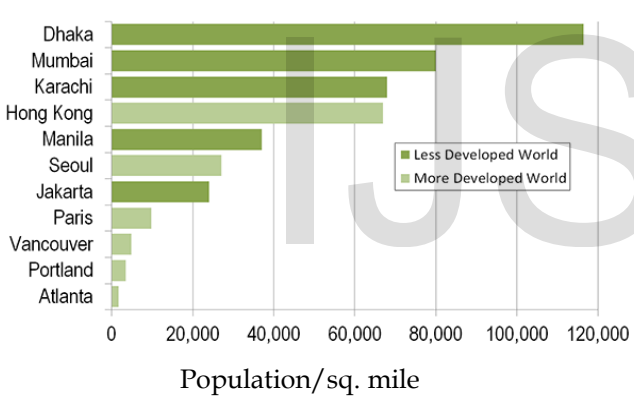

Fig 2. Average population in urban areas in some cities around the world

It is estimated that 40% of the capital city Dhaka's population live in slums under the Dhaka City Corporation (LGED Slum survey, 2005). Some statistical data are stated below as provided by Center for Urban Studies [CUS] Dhaka [10].

Total population of the cities	:15.5 million
Total slum population	:5.4 million (35% of total)
Slum clusters	:9000
Total number of slum households	:1 million
Population density in slums	:200000/sq. km

Over the years, fire broke out very often in these slums causing lost of properties and lives. More than 120 people were killed in June 2010 when a fire at a wedding party destroyed six buildings in the densely populated old part of Dhaka. In 18 November 2012, At least 11 people, all women and children, have died as fire swept through one of the biggest slums in the capital Dhaka destroying more than 500 homes. In 28 June 2014, around 400 homes in a slum in JhutPotti of Mirpur 10 were completely destroyed in a fire, leaving more than 1,000 people homeless. In 11 January 2015, 4-yr-old girl died in Battala slum in Dhaka's Katasur, where a devastating fire ravaged about 400 homes. These statistics indicate the devastating high occurrence rate of fire in this country and the loss is unbearable. Since the slums are highly populated and houses are built too close with very narrow passage ways through them, it is even more critical to perform any rescue operations during the occurrences. So, in order to aware the habitants about the fire, this paper proposes heterogeneous network of fire sensors with smart phones to aware the habitants to secure and save their lives by facilitating faster rescue operation.

3 Proposed System

Conventional fire alarm systems merged with smart phones are capable of sending text messages to the monitoring fire officers using the 3G telecommunication networks. The fire alarm system will turn on the siren for attention of people and to evacuate the place and will send messages to the corresponding authorities. As we studied various fire occurrences in slums of Bangladesh, it was observed that people could not get alerted due to the absence of any fire alarm systems and also due to the sudden severity of fire spread during night while the dwellers were asleep. Our goal is to provide a low cost fire alarm system for the slum people which can aware the dwellers by texting on their mobile phones along with siren and to contact authorities. Since people living in a slum are floating dwellers, we cannot have the list of mobile numbers of the dwellers to contact through the current 3G networks, so we propose for 4G LTE network to implement the service of texting unknown dwellers by d2d communication. In this paper, we propose to merge wireless sensor network with fire alarm system integrated with a 4G smart phone capable of D2D transmission for public safety under LTE network. Since D2D works well in close proximity, it has a certain range such as 30 meters of perimeter to communicate with each other and it can easily establish transmission by paring with nearby devices. Features of this proposal are summarized below:

i. The smart phone will turn on the fire alarm as triggered by the sensor network for identifying fire breakout.
ii. The smart phone will pair automatically with nearby habitant's mobile phone and will send the fire alert signal.
iii. This fire alert signal will ripple to other nearby habitants smart phones and eventually transmit to all.
iv. The passerby people can also get the fire alert signal through d2d communication.

A. Assumptions

- In this paper, we have considered a slum in Dhaka where one square kilometer area will be covered by wireless sensors for simplicity of simulation process.
- The linchpin of the proposed network is a smart phone which will generate fire alarm during fire breakthrough.

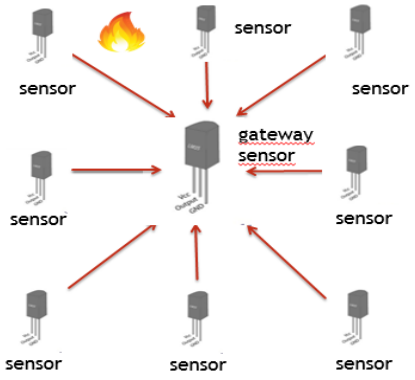

Fig 3. Sensor (source) to gateway sensor communication

- This smart phone of the system and habitats' smart phones must perform d2d communication capable of 4G wireless transmission under LTE network.
- The slum area will be covered with wireless sensor network and the gateway of this network will be the smart phone. As we planned of 1 sq.km slum area, we will need 100 pieces of lm35 temperature sensor to cover the area, so each sensor will have coverage area of 1/100=0.01 Km2.

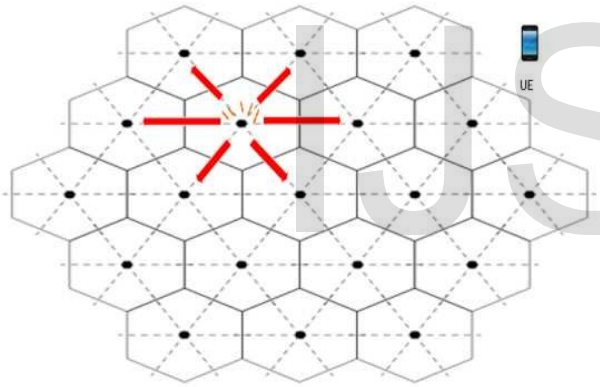

Fig 4. Sensor coverage area

For awareness of the dwellers during fire breakthrough

If fire occurs, the wireless sensors can sense the fire signal, any one of them will transmit the information to the gateway sensor; the gateway sensor will then pass the fire signal to the smart phone deployed within the area; this smart phone will first set the fire alarm to aware the habitants and then it will transmit the fire alert to the habitants and passer-by through d2d communication to their smart phones. As described later, *phase 1* and *phase 2* are designed for awareness of the habitants.

For Recovery and rescue operation during fire breakthrough

The smart phone will also transmit the alert signal to the concerned authorities such as the rescue operators, law & enforcement agencies, emergency health workers etc. The smart phone will be programmed to send message of the fire alert signal to lists of contact numbers of nearest fire brigade, police station, hospital etc. This will be the wireless transmission performed under the LTE core network. As described later, *phase 3* is designed for recovery and rescue operation of the habitats.

B. Network model

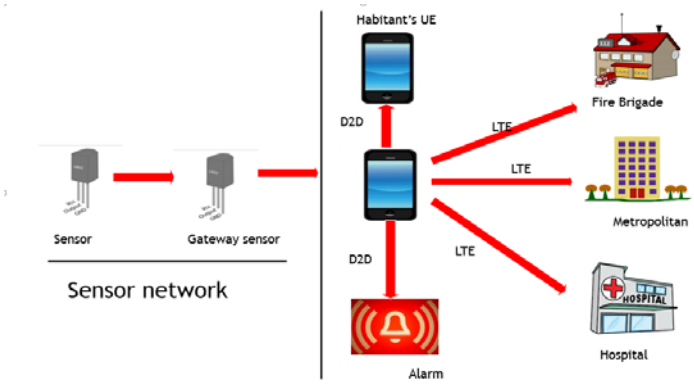

Fig 5. Proposed network diagram

Phase 1: Wireless Sensor network (WSN)

Sensors will detect the temperature of selected area. As all sensors are connected to the gateway sensor through their neighbors, whenever any sensor reads temperature more than or equal 150^0C, the fire signal will be passed to the Gateway Sensor.

In this phase, the fire signal will be transmitted in two steps:

i) Transmit fire signal from sensor (source) to gateway sensor.

ii) Transmit fire signal from gateway sensor to gateway smart phone.

Phase 2: Device to Device Communication (D2D)

The fire signal will be transmitted in the following two steps:

i) Smart phone will trigger the fire alarm for siren.

ii) Transmit fire signal from gateway smart phone to habitant mobile phone by establishing d2d communication.

Phase 3: LTE Communication (LTE)

The last phase requires LTE network for the smart phone to deliver the fire signal to the appropriate authorities. It will work in the following two steps:

i) Transmit fire signal from smart phone to the core network, eNB using the list of contacts of emergency recovery and rescue units.

ii) eNB will propagate fire signal to the metropolitan police, fire brigade and hospital etc.

C. Logical model

Every wireless sensor deployed in the slum will monitor the temperature rise within its area and will send data to the gateway sensor If the temperature is above or equal 150^0C. The sensors used here are the primary source of data about the fire breakout.

Sensor_Temperature:

High_risk: = >150^0C;

No_risk: <=50^0C

Firealert:

Red_state : High_risk [fire breakthrough: alert signal transmission]
Green_state: No_risk [no fire identified]

Proposed Algorithm

Enable Sensor Network and Input values from every Sensor

```
Void Temperature_Sensor(void){
   If (Sensor_Temperature==No_risk){
      Then do nothing;}
   Else If (Sensor_Temperature ==High_risk){
      Then Transmit sensor_signal to gateway_sensor;}}
Void Gateway_Sensor(void){
   While (signal_arrival==sensored_signal){
      Set Alert_signal==Red_state;
      Transmit Alert_signal to smartnode();}}
Void Smart_Node(void){
   While (signal_arrival == Alert_signal){
      Set Fire_Alarm==On;
      Enable D2D_Communication(send Alert_signal){
      Start Proximity services;
      Search for habitant_node &&
      Transmit Alert_signal to habitant_node;
      Search for passerby_node &&
      Transmit Alert_signal to passerby_node;}
      Enable LTE_Communication (send Alert_signal) {
      Process list_of_Contact;
      Transmit Alert_signal to authoritynode;
}}}
```

4 Simulations and Results

We have used omenet+ as our network simulator. Simulation is performed phase by phase as described below:

Phase 1: Wireless Sensor network (WSN)

i) Sensor (source) to gateway sensor communication:

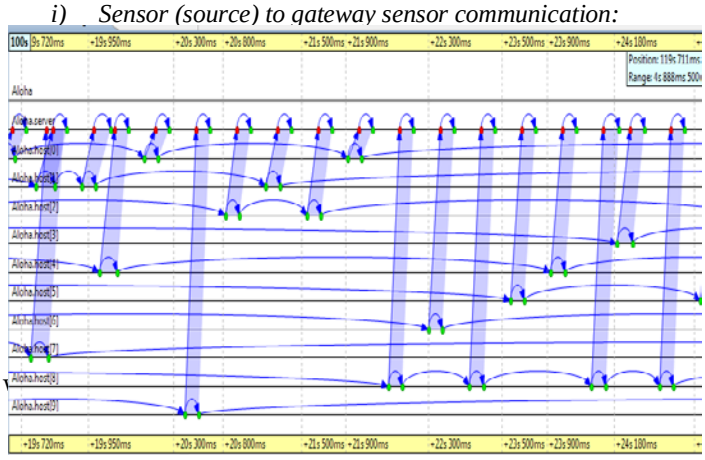

Fig 6. Sensor to gateway sensor communication

Here we have 10 temperature sensors which are connected by a mesh network with the gateway sensor. In this simulation we have used aloha protocol.

Calculated transmit time for transmitting fire signal from sensor (source) to gateway sensor = 10.2 milliseconds.

ii) Gateway sensor to gateway smart phone communication:

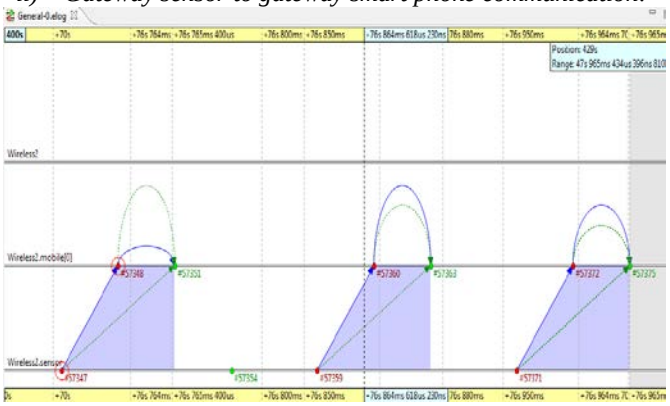

Fig.7. Gateway Sensor to gateway smart phone communication

Calculated transmit time from Gateway Sensor to gateway Smart Phone Communication = 0.816 milliseconds.

A. Phase 2: Device to Device Communication (D2D)

i) Gateway smart phone to alarm communication:

After getting fire signal, the smart phone sets alarm on.

Calculated transmit time from gateway smart phone to Alarm communication = 0.01345 milliseconds.

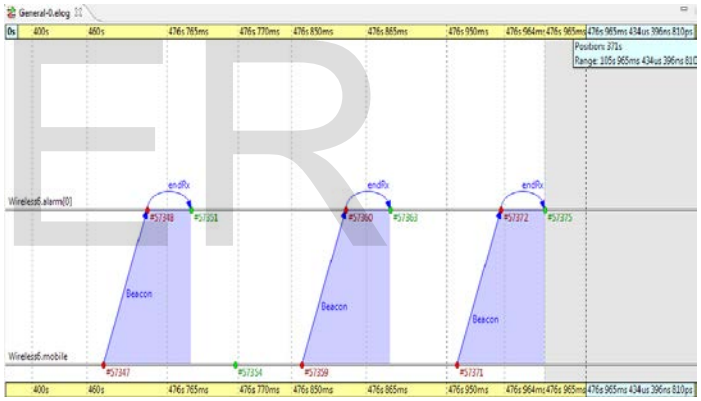

Fig 8 Gateway smart phone to Alarm Communication

So, the total time required **for alarm generation in the slum to make awareness among habitant is around 11.02945 milliseconds.**

ii) Gateway Smartphone to habitant mobile phone communication:

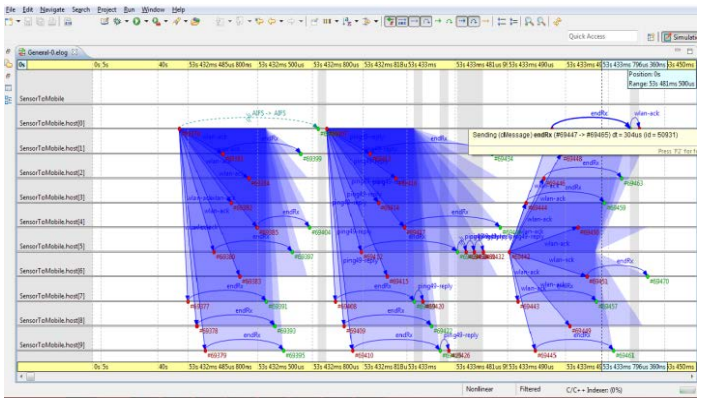

Fig 9. Gateway smart phone to habitant mobile phone Communication

Here we have used flooding protocol.

Calculated transmit time from **gateway smart phone to habitant mobile phone communication = 0.00066 milliseconds.**

So, the total time required for the **Alert Generation among habitant through mobile phone around = 11.01666 milliseconds.**

A. Phase 3: LTE Communication (LTE)

i) Gateway Smart phone to Base Station Communication:

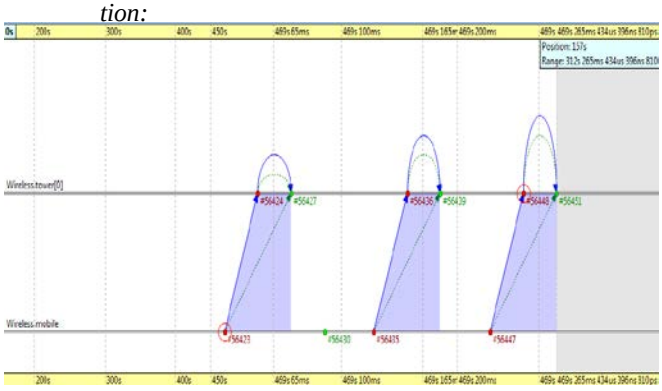

Fig 10. Gateway smart phone to Base Station Communication

Calculated transmit time from gateway smart phone to Base Station Communication = 0.02 millisecond. So, the total time required for **transmit fire information from sensor (source) to base station is around 11.036 milliseconds.**

ii) *BTS* to metropolitan, fire brigade and hospital communication:

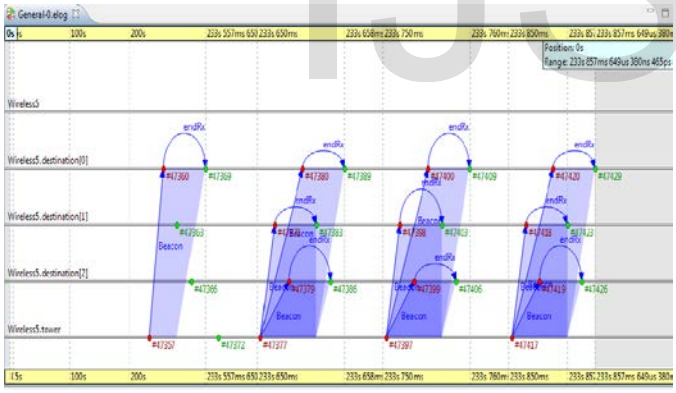

Fig 11. Tower to Metropolitan Communication, Fire Brigade Communication and Hospital Communication

Calculated transmit time from base station to the concerned authorities= 0.001455 millisecond. So, the total time required for **transmit fire information from sensor (source) to responsible authorities is around 11.03745 milliseconds.**

5 Cost Benefit Analysis

As we estimated implementation cost of this proposal of 1 sq.km slum area, we will need 100 pieces of lm35 temperature sensor costing maximum 20 dollar, a smart phone of nearly 120 dollar and an alarm about 10 dollar. So the total estimated budget is = 150 dollar. In case of large area to cover, only the price of the sensors will be in addition of 20 dollar for each 1 sq. km area in consideration.

6 Conclusion

In this paper, we propose a good worth heterogeneous network of sensors, smart phones and fire alarm in a slum area by transmitting fire alert signal to create awareness among the habitats and the responsible authorities for quick rescue operation. Simulation process reveals that e*stimated time required for fire alarm to set on is around 11.02945 milliseconds, for the alert generation among habitats through smart phone is around 11.01666 milliseconds and to transmit the fire occurrence to responsible authorities is around* 11.03745 milliseconds. The simulation results and the cost-effective calculation indicate that we can easily deploy the system in slum area with low cost involvement. As our budget is cheap, government or other non-government organization can easily fund this proposal to make real life project for the poor people and can save thousands of lives. The fire alert signal with sensors and a mobile phone is easy to build with 3G technology and is used in many places. This proposal differs from the existing works as it utilizes device to device communication between the system's smart phone and the habitats smart phones to aware them immediately of the situation. The future 4G mobile phones will hopefully come with the proximity services enabling the D2D communication; then we can properly design and implement the proposed system.

References

[1] Christopher Cox, An Introduction to LTE: LTE, LTE-Advanced, SAE and 4G Mobile Communications, ISBN-13: 978-1119970385 ISBN-10: 1119970385, 1st Ed., Wiley, March 2012.

[2] Peng Li and Song Guo, Cooperative Device-to-Device Communication in Cognitive Radio Cellular Networks, ISBN: 978-3-319-12594-7 (Print) 978-3-319-12595-4 (Online) Springer International Publishing, 2014.

[3] Dimitris Tsolkas, Eirini Liotou, Nikos Passas and Lazaros Merakos , "LTE-A Access, Core, and Protocol Architecture for D2D Communication', S. Mumtaz and J. Rodriguez (eds.), Smart Device to Smart Device Communication, DOI: 10.1007/978-3-319-04963-2_2, Springer International Publishing Switzerland 2014.

[4] Klaus Doppler, Mika Rinne, Carl Wijting, Cássio B. Ribeiro, and Klaus Hugl, "Device-to-Device Communication as an Underlay to LTE-Advanced Networks", IEEE Communications Magazine, December 2009.

[5] Ha-Sung Kong, Jong-Seog Yang and Kwang-Sun Kang, "Development of Smart Phone Applications Linked with Fire Alarm Control Panel in Automatic Fire Detection System", International Journal of Smart Home Vol. 10, No. 2, (2016), pp. 11-18. http://dx.doi.org/10.14257/ijsh.2016.10.2.02

[6] Chang Su Ryu, "IoT based Intelligent for Fire Emergency Response Systems", International Journal of Smart Home Vol. 9, No. 3 (2015), pp. 161-168. http://dx.doi.org/10.14257/ijsh.2015.9.3.15

[7] Wong, H.S., Islam, M.T., Kibria, S.Design and optimization of LTE 800 MIMO antenna (2014) Scientific World Journal, 2014, art. no. 725806.

[8] Wong, H.S., Kibria, S., Islam, M.T., Mandeep, J.S., Misran, "N .Quad band handset antenna for LTE MIMO and WLAN application (2014), International Journal of Antennas and Propagation, 2014, art. no. 341574.G.

[9] Smart Device to Smart Device Communication By Shahid Mumtaz, Jonathan Rodriguez.

[10] Center for Urban Studies, Dhaka, http:// www.*cusdhaka.org*