Pilgrim Tracking and Location Based Services Using RFID and Wireless Sensor Networks

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Summary
Managing a huge crowd and providing them with required services has always been a challenge. Millions of faithful visits the holy sites in Saudi Arabia to perform various rituals, each year. During the event of Hajj, masses of pilgrims gather in Makkah and Madinah making it one of the largest gatherings in the world. Several challenges arise while managing such a huge number of people. These challenges include safety, security and health issues pertaining to pilgrims. This paper proposes to utilize state of the art wireless technology to solve these potential problems. A novel architecture and related algorithms have been presented that use RFID and WSN to provide monitoring, tracking, and location-based services for the pilgrims. Moreover, using the proposed architecture overcrowding issues can also be resolved that can help save many lives. Furthermore, a mathematical based analysis has also been discussed that proves that this proposed architecture can be utilized to solve various challenges related to management of the crowd in general and management of pilgrims in particular.
Key words:
Crowd Management, Location Based Services, WSNs, RFID, Pilgrim Tracking

1. Introduction

Crowd management and tracking is very crucial to successfully organize and conduct big gatherings where there is always a concern of safety and security. For the Muslim World, Makkah and Madinah hold a special importance and a huge number of faithful gather at the holy sites throughout the year and especially during the Hajj season. The two main sites where a lot of crowd is generally observed are Masjid Haram in Makkah and Masjid Nabawi in Madinah. The authorities potentially face a lot of problems related to the health, safety and security of pilgrims. This problem gets worse during the peak seasons of Hajj and the holy month of Ramadan. With the advancement of technology and the potential exploitation of technology for various applications, a solution to these problems is now viable.
Wireless Sensor Networks (WSNs) have been under limelight for the last decade or so. These tiny sensors have potentially transformed the field of microelectronics and communications and are widely being deployed in various applications across multiple disciplines including healthcare, industrial automation, farming and agriculture, pollution, seismic activity and habitat monitoring, military, security and weather reporting [6]. The wireless network of these sensor devices can be formed by distributing them on a large scale. These miniature devices are constrained in terms of memory, processing, battery and communication capabilities. A BSN (Body Sensor Network) is a particular application of wireless sensor networks where multiple sensors either on or in the human body can form a wireless network to communicate several vital health related information with each other.
Radio Frequency Identification (RFID) is used as a very efficient technology for the identification and tracking of different types of objects. The basic principle of RFID includes detecting and identifying a tagged object through the data it transmits. In order to detect and identify RFID system needs a tag, which is also called transponder, a reader, which is called interrogator, and antennae, which is known as coupling devices, located at each end of the system. The reader is usually connected to a host computer or other device that has the needed intelligence to further process the tag data and take action. Typically, the host computer is connected to a larger network of computers in a business enterprise and, in some cases, is connected to the Internet. RFID has a potential to be used in a wide array of applications including public transport, passport control, access control, inventory system, human and animal identification, healthcare, automotive industry etc. [9]
This paper exploits the use of WSNs and RFID system to assist both the pilgrims and authorities in terms of providing them tracking and various other services based on the location. The focus of this paper is Masjid Nabawi, however, this work can later be expanded to cover other holy sites in Makkah. We have suggested to divide total area of Masjid Nabawi into cells where each cell has been proposed to have static readers. These readers are placed in a way to have maximum coverage of the cell. With the help of the base station and the local cell office a lot of services can be provided to the pilgrims. The pilgrims will be carrying an integrated Sensor/RFID tag. Once they come in range of one of the fixed readers, the reader will read the data and will send it to the base station via one or more of the possible links (may be wireless or wired). The reader or the base station will be in a position to take the decision after receiving information. The value they receive can be of two

Manuscript received June 5, 2018
Manuscript revised June 20, 2018

types. One coming from sensors can be related to health issues (like pulse rate, blood pressure etc.) The other can be for the location and tracking purposes. Depending on the type of the value received, the base station or the reader will make a decision to either send a doctor or a security personnel to help the pilgrims in need.

Fig. 1 Masjid-e-Nabawi in Madinah, Saudi Arabia

Masjid Nabawi is second holiest site of Islam. Millions of Muslims visit Madinah and Masjid Nabawi every year especially during Hajj and Umrah seasons. Managing such a big crowd and providing them security and services is a very big challenge for the government here in the Kingdom of Saudi Arabia (KSA). Technology is innovating and adapting itself to solve many critical problems faced by the mankind. We can use wireless technology to seamlessly solve various problems being faced by the authorities towards crowd management.

Fig. 2 Total area of Masjid-e-Nabawi

Total area of Masjid-e-Nabawi is about 617 * 675 meters. When we visit Masjid Nabawi we see that high-class facilities are being provided to the pilgrims, however, we still see a lack of real time implementation of technology. Therefore, we want to propose a smart solution that will not only help the pilgrims and visitors to perform their sacred rituals but also will help the authorities to better manage the crowd and services. With the use of RFID tags each pilgrim can be identified easily. Tracking them in case of a problem would also be very easy. This tracking can have two main benefits, for pilgrims it could help them to know their location in case they get lost and for authorities it could give information to find out congestion in certain areas and the flow of pilgrims can be controlled. Another important benefit to authorities can be to trace illegal workers and to identify dead and injured pilgrims.

In a nutshell, our proposed architecture can potentially solve the following problems:

1. Identifying the pilgrims
2. Locating the pilgrims
3. Tracking the pilgrims during their divine tour
4. Identifying dead or injured pilgrims
5. Tracking illegal immigrants
6. Providing right services at the right time for the pilgrims
7. Crowd Management during the peak times
8. Providing emergency services like ambulance
9. Tracking the health of the needy patients

Additionally, pilgrims can be provided with location-based services like: finding hotels, restaurants, holy sites, parking areas etc. relative to their location

The rest of the paper has been organized as follows. Section 2 talks about the related work in this area of research, section 3 introduces the proposed architecture, section 4 is related to results and finally section 5 concludes the paper.

2. Related Work

[1, 2] propose a pilgrim identification system based on RFID. The authors practically tested their proposed system on pilgrims. The experiments were quite successful and are indicative of the fact that RFID can be deployed in these kinds of scenarios. They narrate that the RFID technology can be used effectively to help pilgrims while they are busy performing their ritual at Hajj. In [3] authors suggest using WSNs by deploying fixed stations at various parts of the holy mosque. They suggest providing emergency services. In [4] authors propose RFID based solution for transportation of pilgrims. [5] suggests the use of backend database to store information about pilgrims and by making use of wireless technology the information can be collected/verified and eventually can help to provide services to pilgrims at airport for example. In [8] authors suggest the use of Sensors and RFID to provide location-based services to the pilgrims in context to pilgrims visiting holy places in Makkah.

All these suggested solutions are very useful and are convincing of the fact that RFID/Sensors can be used in these kinds of scenarios. But they have some drawbacks, firstly their proposed solutions are focused on just Makkah and for Hajj season in particular and secondly, they are providing limited services. We want to first thoroughly research and later suggest such a solution that can provide integrative services that will be useful for both pilgrims and for authorities. Also, our focus is on Masjid Nabawi so that authorities could provide much needed services there by using state of the art technology.

3. Proposed Architecture

Our proposed architecture is based on the simple idea that the existing technologies should be used to provide useful applications for the humankind. Our architecture is proposed by keeping in view the number of people visiting Masjid Nabawi. Following figure is giving an overview of our basic idea. The pilgrims would be carrying an integrated Sensor/RFID tag. Once they come in range of one of the fixed readers, the reader will read the data and will send it to the base station via one or more of the possible links (may be wireless or wired). The reader or the base station would be in a position to take the decision after receiving information. The value they receive can be of two types:

1. Reading coming from sensors, this can be related to health issues (like pulse rate, blood pressure etc.)
2. GPS or location related data that can be used for the tracking purposes and also to provide location based services.

Depending on the type of the value received, the base station or the reader would be able to make a decision to either send a doctor or a security personnel to help the needy pilgrim.

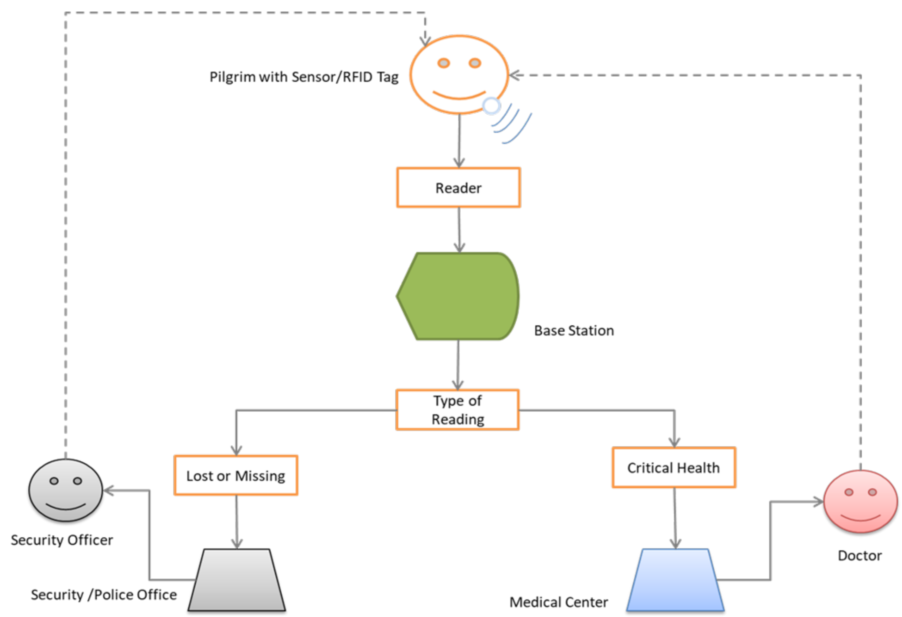

Fig. 3 Overview of the Basic Design

Before going any further, we would like to state our assumptions:

1. The complete area of Masjid Nabawi has been assumed to be divided into equal cells.
2. Each cell has three static reader installed at pre-defined locations in a way to maximize the reading range and the coverage of the cell.
3. We assume a multi-tier heterogeneous network.
   a. The first tier is comprised of energy constrained integrated RFID tags/sensors.
   b. The second tier is comprised of a resource rich set of reader nodes. These reader nodes are thought to be connected to each other and the local cell office which in turn connected to base station using a backbone wired network.
4. The local cell office and the base station are connected to the hospital.
5. We assume that the node are static except for pilgrim nodes which are mobile but are connected to only one reader giving the output.

This whole situation can be understood with the help of the following figure:

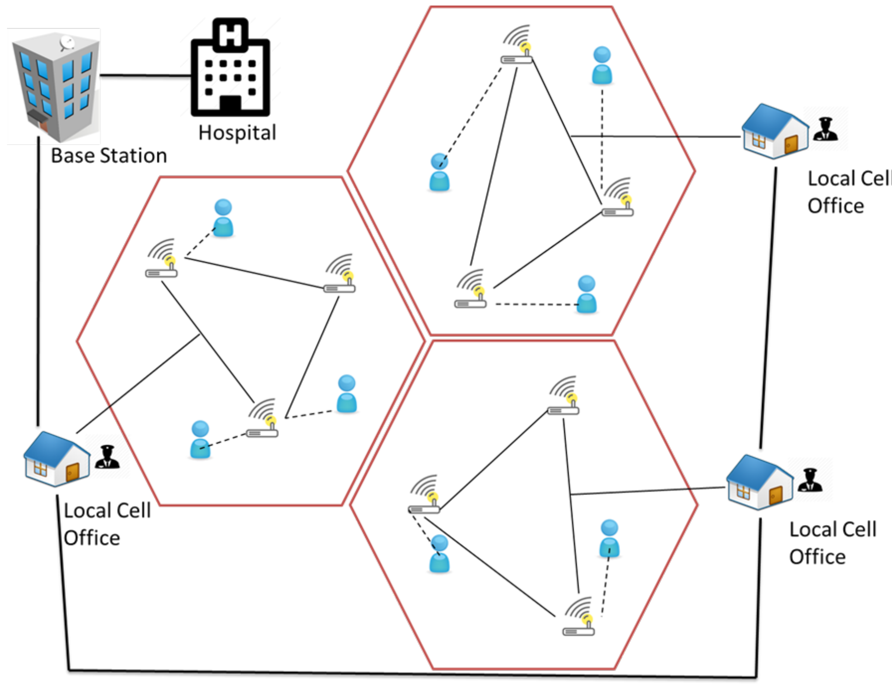

Fig. 4 Cell Based Division of the Masjid Nabawi

Figure 5 is explaining the general flow of information. The pilgrim is identified by the reader. Reader is actually responsible to get the ID and the other sensor readings. After getting the reading the reader can communicate with the local cell office. The local cell office possesses a local copy of the database. The ID and information can be verified here. If it is not present here the local cell office is connected to rest of the local cell offices and also with the base station via a high-speed backbone network. Depending upon the need, the local office can act to contact the hospital or can communicate with the security to perform any desired operation to help the pilgrims. The base station contains all the data which is collected from all the cells. The data in base station is regularly updated. In case of any need, the base station can also communicate with the hospital directly.

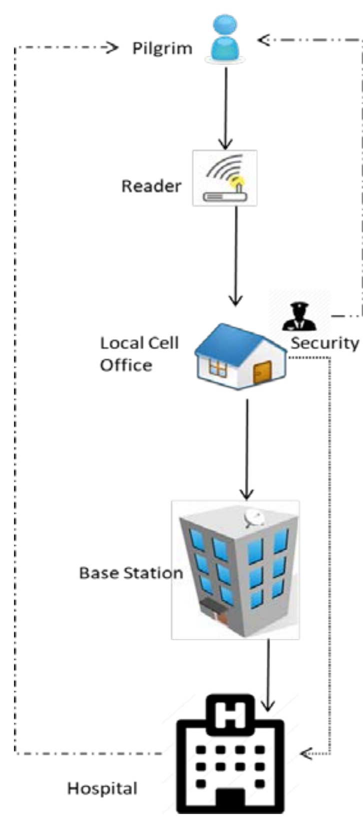

Fig. 5 Stepwise Communication Pattern

Now we would like to explain the algorithms that we have proposed for this architecture. Figure 6 to Figure 10 throw some light on the detection event, emergency services, security services, location-based services and update operations of the base station.

Figure 6 is our proposed algorithm related to the event a) once the tag gets in range of a particular reader b) a query or identification requirement can be sent from the reader or base station to the tag.

```
RFID_READER_DETECT_SERVICE
   If the reading is a query  //Check the type of reading
     then
        Search database  //see if the id already exists in the database
              If match found  //if it is the registered ID
                then
                   if the query type is emergency service request
                     //need special attention
                   then

                     CALL_EMERGENCY_SERVICE(ID,LOCATION
                     ,EMERGENCY_LEVEL)  //contact the hospital
                    if the query is lost report  //pilgrim is lost
                    then
                      CALL_SECURITY_SERVICE(ID,LOCATION)
                     //dispatch security from local cell office
                    if the query is to search neighborhood  //pilgrim
                     wants to find areas of interest
                    then

                     CALL_AROUND_ME_LOCATION_SERVICE(I
                     D,LOCATION,QUERY) //give info. of interest
             else
                Ignore the reading(SEND_ERROR_MESSAGE)
   else if the reading is a response
      then
              update location  //update local database against the ID
                   of pilgrim with current location
              update sensor readings //update latest health readings
                   against ID of pilgrim
              CALL
                   UPDATE_BASE_STATION_SERVICE(UPDATE
                   S) //report back to the base station with latest
                   updates
```

Fig. 6 Algorithm to Get a Reading from the Tag/Sensors

Figure 7 explains the algorithm related to calling the emergency services. There can be many situations that can trigger this service a) If the patient gets in the critical state due to some medical condition b) Looking at the reading of the patient the local cell center decides to dispatch the medical team to attend the pilgrim c) Looking at the data records of the patient the base station or the hospital decides to attend the patient

```
EMERGENCY_SERVICE (ID,LOCATION,EMERGENCY_LEVEL)
   If EMERGENCY_LEVEL equals SEVERE //Check if patient
need  immediate attention
     then
        DISPATCH_EMERGENCY_TEAM
   else if EMERGENCY_LEVEL equals HIGH //Check if patient is
not in danger but needs attention
        CONSULT_DOCTOR
        DISPATCH_EMERGENCY_TEAM
   else if EMERGENCY_LEVEL equals MEDIUM //Check if there
might be a possibility of health issue
        CONSULT_DOCTOR
        REQUEST_ANOTHER_READING //get latest reading from
patient
        if RE_READING_IS_SEVERE_OR_HIGH //patient is still
critical
        then
          DISPATCH_EMERGENCY_TEAM
        else
          UPDATE_PATEINT_RECORD
          CALL UPDATE_BASE_STATION_SERVICE(UPDATES)
//report back to the base station with latest updates
   else if EMERGENCY_LEVEL equals LOW //Check if the patient
```

Fig. 7 Algorithm for Emergency Service

Figure 8 is explaining the steps required to call the security services

```
SECURITY_SERVICE(ID,LOCATION)
    DISPATCH_SECURITY_TEAM
    UPDATE_PILGIRIM_RECORD
    CALL UPDATE_BASE_STATION_SERVICE(UPDATES) //report
back to the base station with latest updates
```

Fig. 8 Algorithm for Security Service

Figure 9 is explaining the algorithm related to the location service.

```
AROUND_ME_LOCATION_SERVICE(ID,LOCATION,QUERY)
    SEARCH_QUERY
    REPLY_QUERY  //give information about the location of interest
```

Fig. 9 Algorithm for Location Based Services

```
UPDATE_BASE_STATION_SERVICE(UPDATES)
    UPDATE_DATABASE_WITH_LATEST_RECORDS
    perform analysis on the patient record if required:
       DISPATCH_EMERGENCY_TEAM
```

Fig. 10 Algorithm to Update the Base Station

4. Results and Discussion

Our proposed architecture comprises of a heterogeneous network with three different kind of nodes as explained in

Figure 11. All the nodes (base station to local cell office and local cell office to gateway/reader node) are connected via high speed and reliable network as proposed in [6] in order to increase the reliability of the communication.

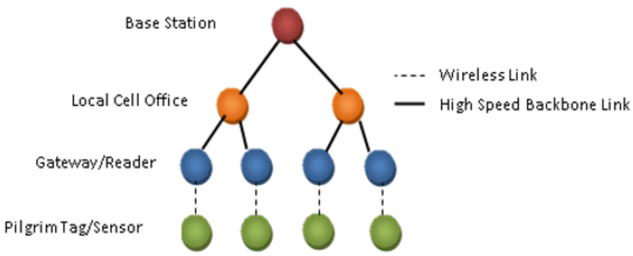

Fig. 11 Different Nodes of the Network and their Links

The number of tag/sensors are expected to be much more in comparison to the nodes at the higher level. i.e. Gateway/Reader nodes. The obvious reason is the sheer number of visitors in the target location. We have proposed to divide the whole area of Masjid Nabawi into cells. Each cell has number of Gateway/Reader nodes pre-installed at such locations so that the most or all of the cell gets into the reading range of any one of the readers at minimum. To come up with an appropriate number of readers per cell is very essential. Since it will affect both the cost and effectivity and reliability of communication and eventually intended services for the pilgrims. The size of each cell will also play a significant role. In cellular communication the size of the cell is a very well researched topic. Generally, speaking, there are three kinds of cells 1) Macro Cells, where the size of each cell varies between 1 km to 20 kms 2) Micro Cells, where the size of each cell varies between 400 meters to 2 km and 3) Pico Cells, where the size of the cell varies between 4 to 200 meters [10]. To come up with an appropriate size of the cell has been left for later research and has not been discussed in this paper. However, we will see some mathematical analysis between various crucial factors. Let's assume there are γ number of sensor nodes in each cell and β number of readers for that particular cell. Here we know that:

$$\beta \ll \gamma$$

Alternatively,

$$\beta = C\,\gamma \qquad (1)$$

Here C represents a ratio between γ and β and is in the range $0< C < 1$. In other words, C signifies the occurrence of reader nodes in comparison to the sensor nodes per unit distance. If the value of C gets close to 1 that will mean that the cell will have a good coverage since the number of reader nodes will be appropriate will cover most of the cell. Figure 12 and Figure 13 show the relationship between 'C' and number of reader and sensor nodes. In figure 12 reader nodes have been kept constant whereas in figure 13 sensor nodes have been kept constant.

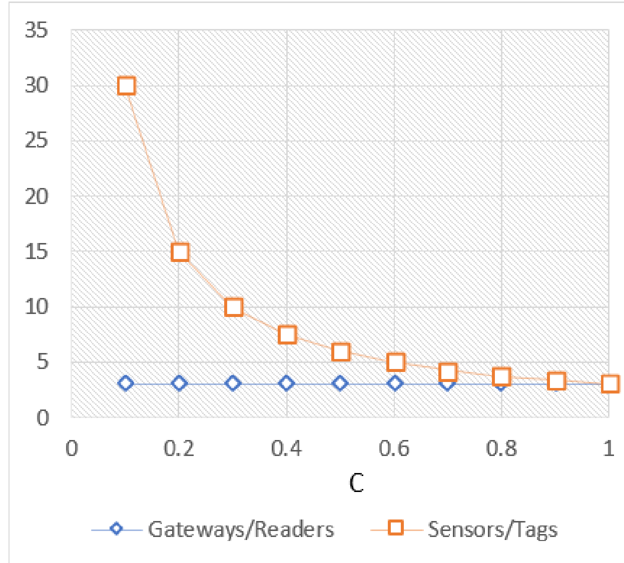

Figure 12: Varying value of γ with constant value of β against C

Figure 12 shows when the ratio C gets closer to 1 the number of sensor nodes go to their minimum number on the other hand when the ratio gets closer to 0 the number of nodes go their maximum number. In other words, when the value of C is bigger the cell gets sparse in terms of presence of sensor nodes and when the value of C gets lesser the cell gets denser.

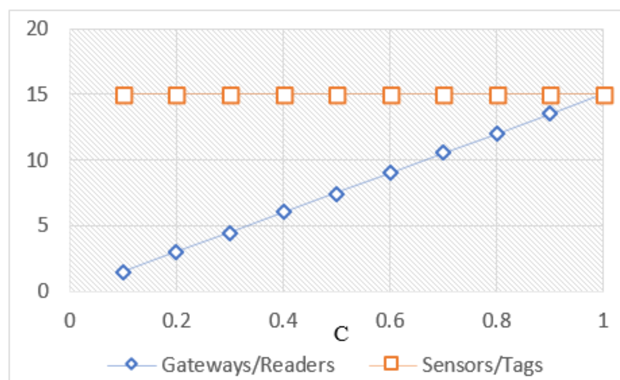

Figure 13: Varying value of β with constant value of γ against C

Figure 13 shows when the ratio C gets closer to 1 the number of reader nodes go to their maximum number on the other hand when the ratio gets closer to 0 the number of reader nodes go their minimum number. In other words, when the value of C is bigger there will be more number of reader nodes per cell with a better coverage and when the value of C gets lesser then there will be less number of reader nodes per cell with a poor coverage.

The above discussion proves that the value of ratio should be adjusted in a way that the cell gets appropriate coverage especially for the cases when the cell gets heavily dense.
Let's assume 's' is the size of each cell. We can observe the following relation:

$$s \propto \beta \tag{2}$$

Alternatively,

$$s = E\,\beta \tag{3}$$

E represents transmission range of the reader nodes. The value can vary between 1 to n. It is obvious from equation 2 that the size of each cell is directly proportional to the number of reader nodes for that particular cells. Bigger the size of the cells bigger is the number of required reader nodes for that cell. In other words, the number of reader nodes are dependent on the size of each cell.

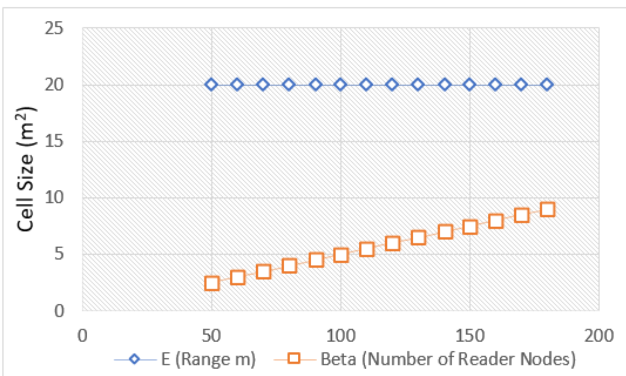

Figure 14: Relationship between size of the cell and reader nodes (β)

Figure 14 shows the graph based on equation 3. The data has been randomly generated also the value for the transmission range of the sensor nodes has been assumed to be 20 m and has been kept constant for comparison purposes. The figure clearly shows that when the size of the cell increases the number of required reader nodes increase in order to keep a good coverage of the cell provided that the transmission range of the reader node is kept constant.
Let us further assume that the probability that a reader node will successfully receive a reading from the sensor is P and consider D is the distance between the sensor node and the reader node. We can come up with the following equation:

$$P \propto 1/D \tag{4}$$

Alternatively,

$$P = F/D \tag{5}$$

Here value of F represents possibility of having obstructions during the transmission between the reader node and the sensor node. The value can vary in the range of 0 < F <= D.

Equation number 4 shows that the distance between the sensor and the reader node is inversely proportional to the probability of a successful communication between the reader and the sensor node. In other words, more the distance between the sensor and the reader less will be the probability of successful communication and less the distance more will be the success probability.

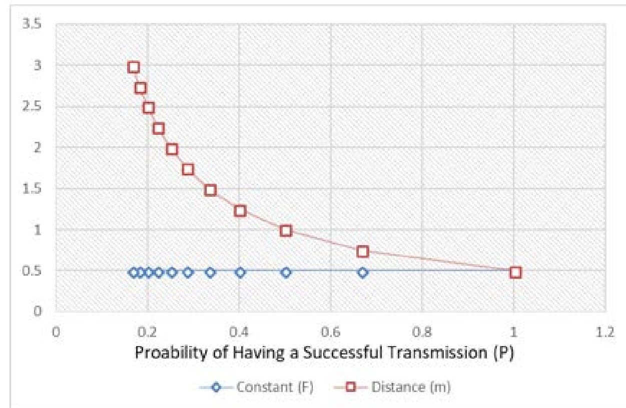

Figure 15: Probability of Having a Successful Transmission versus Distance

Figure 15 is based on the equation number 5. It can be seen clearly that the maximum probability of success is when the distance between the sensor node and the reader node is kept at the minimum. On the other hand, as the distance increases the probability of success decreases.

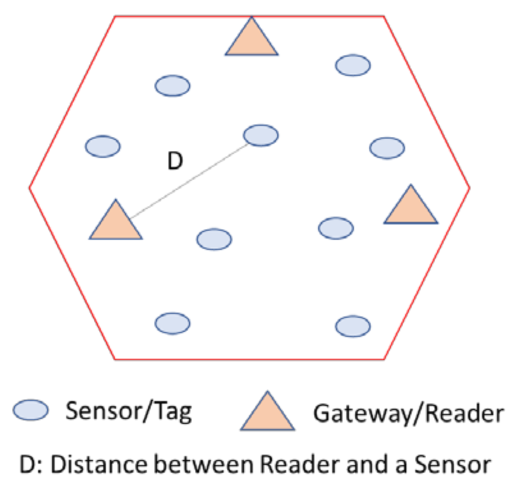

Figure 16: Occurrence of Sensor/Tag and Gateway/Reader Nodes

5. Conclusion and Future Work

This paper presented a novel architecture for the betterment of pilgrims who visit the holy places in Saudi Arabia. The focus of this study was to cover Masjid Nabawi in Madinah. A number of algorithms have been proposed to support crowd management in general. The proposed architecture and algorithms are based on sate of the art technology and use RFID systems and WSNs. It would make a lot of services available for the pilgrims including emergency services, health monitoring, and several location-based services. The proposed system, with the use of RFID tags, would also help authorities to track and identify pilgrims. Another important benefit to authorities could be to trace illegal workers and to identify dead and injured pilgrims. A comprehensive analysis has also been presented that supports the use of these technologies for the good of the pilgrims and authorities. In future, the research will further be refined by including other holy places and performing simulation and later creating a prototype to conduct real time tests on the pilgrims.

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