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Impact of Mobile Sink Speed on the Performance of Wireless Sensor Networks

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ABSTRACT

This paper investigates the impact of mobile sink speed on the performance of Wireless Sensor Networks (WSNs). Sensor networks are distinguished from traditional networks by characteristics such as deeply embedded routers, highly dynamic networks, resource constrained nodes, frequent topology change and unreliable and asymmetric links. In this paper, we propose a novel, simple and efficient approach to evaluate the ability of data transmission and reception of WSN to or from a mobile sink on the basis of its speed, direction and distance, with regards to the network. Simulation results are given, which show that this approach help evaluate the desired system performance under the dynamically changing network.

Inspec Classification: B6210L, B6250, C3120

Keywords : Wireless Sensor Networks (WSNs), Dynamic network, Embeded Router

1) UNDERSTANDING THE SCENARIO

A wireless ad hoc sensor network is a collection of battery-powered devices which have very small processors, and are typically communicate by radio. They are designed to be cheap enough that they can be deployed in large numbers (thousands, hundreds of thousands), in order to take comprehensive measurements from the environment (J.E. Tateson, 2006). Typical sensing tasks for such a device could be temperature, light, vibration, sound, radiation, etc. (H. Karl). These sensor nodes are not only capable of harvesting information from the environment, but also perform simple processing on it, and transmit it to the sink (I.F. Akyildiz, 2002). a node responsible for collecting such data. Research community has been doing research on WSN for last few years. This is due to the fact that WSNs are constrained by different factors like lack of global knowledge, reduced energy (as sensor nodes are not rechargeable), and minimal computational ability of the individual nodes. The research results in the development of new applications such as tracking, home automation, and environmental monitoring which can be achieved by these micro sensor devices. In (I.F. Akyildiz, 2002), authors listed some other applications of WSN, which include Multimedia surveillance sensor networks, storage of potentially

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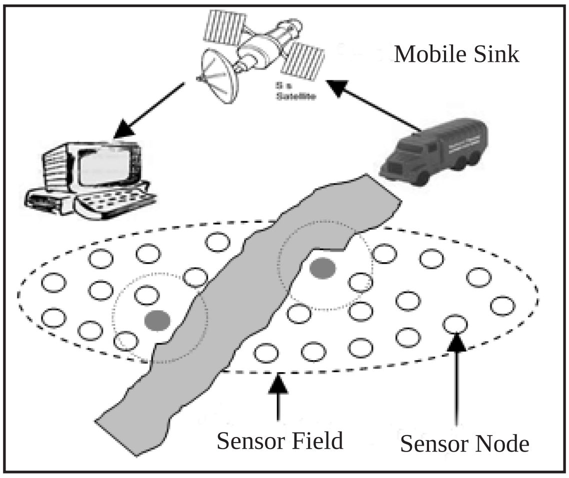
relevant activities, traffic avoidance enforcement and control systems, advanced health care delivery, automated assistance for the elderly and family monitors, environmental monitoring, person locator services, and industrial process control. In addition to these application areas, a new application area of WSN has explored recently in (G.W. Allen, 2006), in which sensor nodes are deployed in an active volcano to get the acoustic measurements from it. From the above discussion, we can say that the collective responsibility of sensor nodes is to provide their comprehensive measurements to sink, where useful information can be extracted from it.

Fig 1:
Wireless Sensor Networks



The sink may or may not be a mobile node. In (G. Mergen, 2006), authors use a term SENMA (sensor network with mobile access) for such mobile sinks, where a number of low cost energy constrained nodes access a powerful mobile node for their data transfer.

The position of sensor nodes need not be engineered or predetermined. This allows random deployment in inaccessible terrains or disaster relief operations. On the other hand, this also means that sensor network protocols and algorithms must possess self-organizing capabilities (I.F. Akyildiz, 2002).

In situations where SENMA technique is being utilized, there are many ways of mobile access. In (G. Mergen, 2006), an airplane has been used as mobile sink, which is not a practical approach, as the sensor nodes have limited energy and transmitting ability. However, a ground vehicle as a sink is more practical approach in many defense and disaster-relief applications. Similar sensor network model with land mobile access, as shown in fig.1, has been discussed in (B. Ren, 2006).

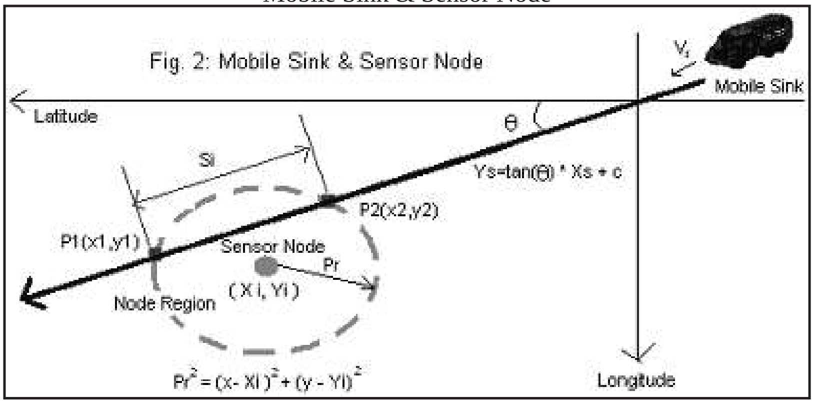
We extend such sensor network model with a different approach of mobile access. We evaluate the ability of the data transmission and reception of a sensor network to or from a mobile sink, on the basis of its speed, direction and distance with regards to the network. Such evaluation not only provides the extent of the impact of these variables on the network's data carrying ability, but also sets up a criterion for designing future wireless sensor networks employing with land mobile sink access.

Wireless sensor networks have recently received a lot of attention in the research literature; a good recent survey paper is [8]; inspirations for possible applications are given in (A. Cerpa, 2001), (D. Estrin, 2001), (J.M. Khan, 1999), (A. Mainwaring, 2002), (S.S. Pradhan, 2002), (F. Siegemung, 2002), (M. Srivastava, 2001), (F. Zhao, 2002).

2) MODEL DESCRIPTION

For simplicity, we assume that the nodes are uniformly distributed.

Fig. 2:
Mobile Sink & Sensor Node



In Fig. 2, a mobile sink is moving towards the sensor field with a velocity of Vi, making an angle θ with the latitude. The path of the mobile sink can be defined by the straight line equation:

$$y_s = \tan\Theta \times x_s + c \quad \text{----------------------------- (1)}$$

Where,

(x_s, y_s) is the current position of the mobile sink,
tan θ is the slope of the straight line which represents the path of the mobile sink, and
c is the y-intercept (or longitude intercept).

For an i[th] sensor node which is placed at the location **(Xi, Yi)**, the power transceiver range $\mathbf{P_r}$ can be defined by the equation of the circle:

$$P_r^2 = (x - X_i)^2 + (y - Y_i)^2 \quad \text{----------------------------- (2)}$$

The mobile sink can only receive the data from the i[th] node if it is within the power range of the i[th] node.

When the mobile sink enters in the power range of the i[th] node, the intersection point is P_1. While when the mobile sink exits from the power range of the i[th] node, the intersection point is P_2.

The points P1(x1, y1) & P2(x2, y2) are calculated by the intersection of straight line's Eq.1 (sink's path) and circle's Eq.2 (node region) as follows:

$$x_{1,2} = X_i \pm \sqrt{\mathrm{Pr}^2 - c^2 - Y_i^2 - mx_s(2c + x_s) + 2Y_i(mx_s + c)}$$

$$y_{1,2} = \tan \Theta \times x_{1,2} + c$$

Where,

- m is the slope of the intersecting line,
- c is the speed of light (c=3*108 m/s),
- P_r is the radius of the node's region,
- x_s and y_s are the coordinates of the mobile sink and
- X_i and Y_i are the coordinates of the node

The connecting time of mobile sink with i^{th} node is given by:

$$T_i = \frac{S_i}{V_s} \quad \text{Where,} \quad S_i = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Total Data Received by the mobile sink:

$$Data(Mbits) = r_d \times \sum_{i=1}^{N} T_i$$

Where, N is total number of nodes & r_d is data rate of node.

3 SIMULATION & RESULTS

3.1 Simulation Setup

To investigate the impact of mobile speed on the performance of WSN, we generate sensor network with 50 nodes and carry out extensive simulations.

In fig 3a, the receiving data packets increase exponentially with the increase in data rate of nodes at constant power range of 15m and at a constant angle of -20 degree form by the mobile sink. So at data rate of 50kbps, we are receiving maximum data packets. Fig 3b shows the dependency of data reception on power range at a constant data rate of 10 kbps and at a constant angle of -20 degree form by the mobile sink. The greater the power range of nodes (in this case 25m), the maximum data we can receive. Fig 3c shows the dependency of data reception on the distance of mobile sink with the nodes i.e., angle formed by the mobile sink at constant power range of 15m and at a constant data rate of 10 kbps. If the sink passes very near to the node, then we can get maximum data packets. Fig. 3d shows the simulation setup i.e., data received by the mobile sink at transmission power range of 15m, data rate of 10kbps and angle of -20 degrees.

Fig. 3 (a-p):
Receiving data packets at different speed

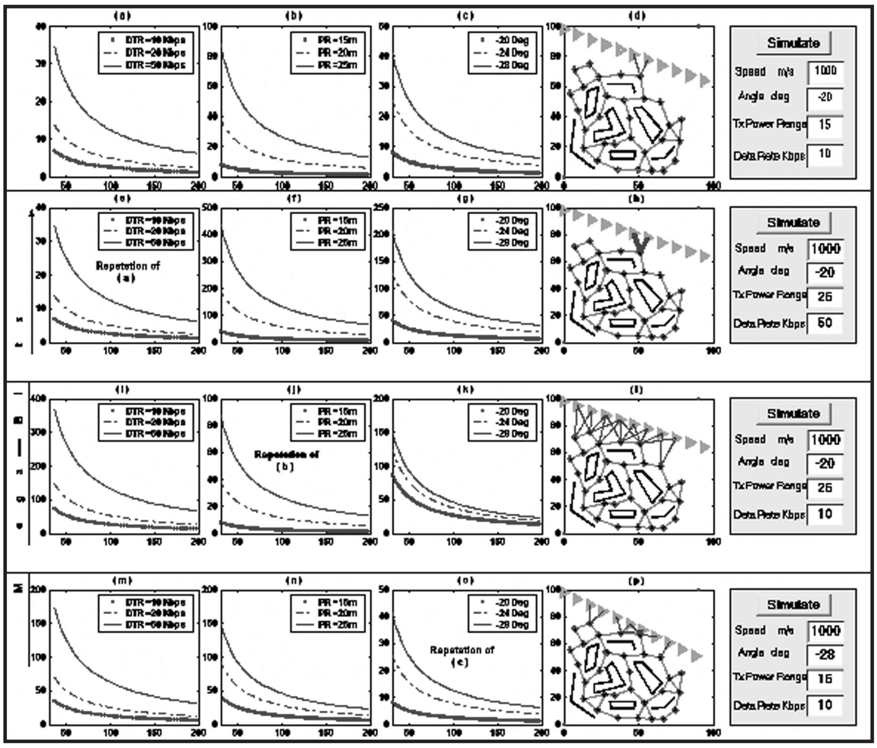


Fig. 3: shows that the receiving data packets at different speeds, are dependent on three parameters : (1) data rate of nodes (DTR), (2) power range of nodes (PR) and (3) direction of mobile sink (Deg). In fig.3(a-d), DTR=10Kbps, PR=15m and Deg=-20. In Fig. 3(e-h) DTR=50Kbps, PR=15m and Deg=-20. In Fig.3(i-l), DTR=10Kbps, PR=25m and Deg=-20. In fig. 3(m-p), DTR=10Kbps, PR=15m and Deg=-28.

For second simulation setup, we are changing the data rate from 10kbps to 50kbps. The other parameters are same as in first simulation. By comparing Fig. 3b & 3f, we can observe that we get five times more data in Fig. 3f due to the higher data rate. Similarly, by comparing Fig 3c & 3g, we get again five times more data in Fig. 3g. It is also due to the higher data rate. In Fig. 3h, the dark blue line shows the high data reception.

For third simulation setup, we are changing the power range from 15m to 25m. The other parameters are same as in first simulation. By comparing Fig. 3a & 3i, we can observe that we get ten times more data in Fig. 3i due to the greater power range. Similarly, by comparing Fig 3c & 3k, we get approximately four times more data in Fig. 3k. It is also due to the greater power range. In Fig. 3l, the different blue lines connected with mobile sink show the higher connectivity between the mobile sink and nodes.

For fourth simulation setup, we are changing the angle from -20 degrees to -28 degrees. The other parameters are same as in first simulation. By comparing Fig. 3a & 3m, we can observe that we get five times more data in Fig. 3m due to the closeness of sensor nodes with the mobile sink. Similarly, by comparing fig 3b & 3n, we get approximately two times more data in Fig. 3n. It is also due to the the closeness of sensor nodes with the mobile sink. In Fig. 3p, the different blue lines connected with mobile sink show the higher connectivity between the mobile sink and nodes.

Thus, Fig 3 shows that the maximum data delivery in WSN depends upon some major factors: 1) data rate & power range of nodes and 2) direction & speed of mobile sink. From this, we can conclude that these factors must be considered before the installation of WSN setup and that we can achieve maximum data reception by focusing on these parameters. So these should be considering prior to the selection of any particular routing algorithm.

4) CONCLUSION & FUTURE WORK

This paper formulates an approach to evaluate the ability of data transmission and reception of WSN to a mobile sink on the basis of its speed, direction and distance and simulated the relationship of the total received data with respect to the data rate, power range and the direction and speed of the mobile sink.

Our future plan is to extend our already proposed routing protocols for WSN. The wired networks, unlike wireless sensor networks, are not limited by energy, node failure due to physical reasons, and lack of a centralized controller. It is therefore, easier to design and model a real-time wired network system. However, due to inherent problems of multi-hop wireless sensor networks, the design of a routing protocol, which is both Quality of Service (QoS) and energy aware is a challenging problem.

Our new protocol will be based on quasi-centralized or multi-gateway architecture, which is efficient, energy-aware and allow gateway mobility. Introducing sink mobility in the protocol while ensuring robustness in an energy efficient manner will increase the capability of WSN.

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