Experimental Design and Analysis of Vehicle Mobility in WiFi Network

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Abstract

Instead of using static nodes in wireless sensor network, implementation of hardware and mobile environment are challenges of mobile wireless sensor network. Mobile sensor nodes combined with wireless network is one of research area and mobility is one of key factors in designing mobile wireless sensor network. To analyze vehicle mobility, this work implements a mobile sensor node in WiFi network and it is equipped with ultrasonic sensor and ESP8266 NodeMCU. The sensor data can be monitored on ThingSpeak over the internet via wireless LAN and its measurement can be taken within 10 s delay. MikroTik (RB931-2nD) router is used as an access point in system architecture. Experiments are performed to study mobility effects on network throughput when mobile sensor node is moving with constant velocity of 10 cm/s. With connectivity in wireless LAN 802.11/n technology, signal strength and throughput are measured for vehicle mobility.

Keywords: *Vehicle Mobility, WiFi, Mobile Wireless Sensor Network, ThingSpeak, Throughput Analysis*

I. INTRODUCTION

Several mobility patterns can be classified as follows; pedestrian, vehicles, aerial, robot and others. Regarding mobility in wireless sensor network with WiFi connectivity, reducing friction and allowing high speed can be obtained in wheel based vehicular mobility. To prevent collisions, all vehicles are planned to move in paths for bounded in 1D movement. In this work, assumption on constant speed and linear movement are made to be bounded in mobility pattern. A mobile sensor node is implemented as parasitic mobility. This mobility pattern can present sensor network performance where sensor node harvests the mobility from vehicle. To measure mobility pattern in wireless sensor network, localization of sensor node can help to analyze the network behavior [1]. In this paper, measuring vehicle mobility is analyzed by using range-based localization technique. In this ultrasonic sensor based for range information, basic principles of ultrasonic range finder are used to be implemented with Arduino. Experimental study is done for analysis of mobility in connectivity of wireless local area network. The rest of paper is organized as follows: related work is described in section 2. Definition and assumption in this paper is mentioned in section 3. Section 4 gives the results and discussion and section 5 gives the conclusions of this work.

II. RELATED WORK

The research work on mobility are studied in literature and presented in sections 2.1, 2.2 and 2.3.

A. Localization in Mobility

Mobility can help to solve the typical problems such as low node density, obstacles and concave topologies. In addition, mobile assisted localization can give better localization accuracy and coverage. Survey of localization problems and solutions are analyzed for wireless sensor network in [2]. In wireless sensor network, range free localization techniques can be used for moving target nodes. In [3], localization algorithm was used to demonstrate localization accuracy and stability. The dynamic aspect of network coverage can be characterized and identified in [4] on the process of sensor movement in optimal mobility strategies.

B. Network Topology in Mobility

Due to the mobility of mobile node, network topology can change significantly for long time scale. Several researches considered mobility effect in Ad Hoc network model. In [5], per-session throughout is kept constant with increasing number of nodes per unit area when users move independently around the network. Investigation of node mobility effect in finding best relay node are proposed in [6] to improve the throughput in Ad Hoc network model. Ad hoc is one of wireless mesh typology. Rapid growth of IoT applications, mesh typology is attractive for heterogeneous network in which coverage is one of factors [7].

C. Mobility in Wireless Sensor Network

Data drive is the main difference between sensor network and mobile Ad Hoc network. Instead of using static sensor node in network, mobile sensor nodes are necessary in real applications. In [8], mobility, typology and localization are key factors in designing mobile wireless sensor network. The mobility and sharing of internet enabled wireless sensor network are analyzed for specific applications [9]. Hardware cost is one of design challenges for implementing mobile sensor node in wireless sensor network. Nowadays, microcontroller-based sensor nodes are easily implemented with additional unit of localization finder to be implemented a mobile sensor node.

III. DEFINITION AND ASSUMPTIONS

In this section, definition and some models that used in this paper is introduced.

A. Throughput

Throughput of the network is the sum of per-node throughput for all nodes in a network. Per-node throughput of λ(n) bits/s can be defined as the time average of transmitted bits by each node to its destination [10]. In this work, destination is gateway router. In a network, per-node throughput capacity is of order of f(n) bits per second if a deterministic constant $0<c1<+\infty$.

B. Network Model

Assumption in this network is that all n mobile sensor nodes are independently and randomly distributed in defined area. To localize parasitic mobility, generated traffic denoted as λ(n) bits/s at each sensor node is dependent of vehicle mobility process. A mobile sensor node sends a packet directly to fixed router if it is within transmission range of mobile sensor node.

C. Random Direction Mobility Model

In this mobility model, mobile sensor node must travel within defined area at a constant speed and direction. After the nodes pause, a new direction and velocity is chosen randomly and then the process will repeat [11]. The parameters for point-to-point segment *i* is as random variables with the following uniform distributions:

- Absolute angle $\varphi_i = \Phi$: uniform $[0, 2\pi]$
- Distance traveled l_i = L: uniform[Lmin, Lmax]
- The speed v_i = V: uniform[Vmin, Vmax]
- The pause t_i = T : uniform[Tmin, Tmax]

IV. TESTS AND RESULTS

To summarize the entire system work in Fig. 1, the system comprises three portions: wireless mobile sensor node, fixed router and monitoring server.

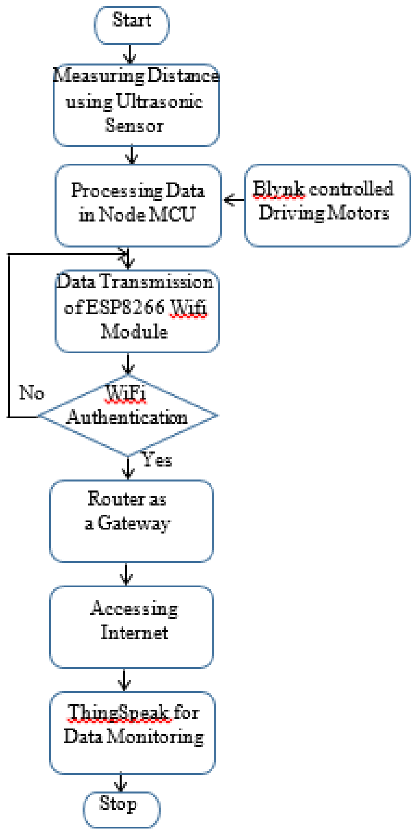

Figure 1. Flow chart for system process

Wireless mobile sensor node senses the distance between it and the facing obstacles by using an ultrasonic sensor. Fixed router receives the packages from mobile sensor node and routes them to the destination. And the ThingSpeak IoT analytic platform is used as a monitoring service provider in this system.

All the router configuration is managed with the use of Winbox software. For local network, IP address of Mikrotik router is set to 172.20.23.17 with a subnet mask of 255.255.255.240 whose prefix is (/28). DHCP server is configured in the router. For WiFi interface, configuration includes WiFi hotspot creating and setting authentication features for wireless protocol IEEE 802.11. For monitoring sensor data on ThingSpeak, a new channel is created after creating user account. Unique channel ID 774771 is used in testing and the feed data of channel can be viewed with private access or public access. There are two API keys and feed data is imported as a CSV file format. For connectivity of ThingSpeak server and NodeMCU, ThingSpeak library is installed in the Aurdino IDE software.

A. System Description

The system shown in Fig. 2 is developed to measure and analyze the throughput of wireless network, according to measured distance while moving one mobile node in this network.

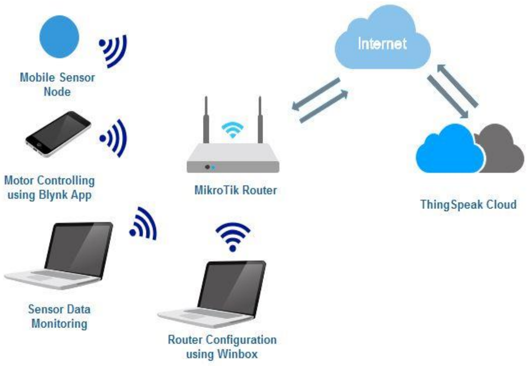

Figure 2. System architecture

The vehicle is moved in WiFi network as mobile sensor node. It is constructed by using ultrasonic sensor and ESP8266 NodeMCU WiFi module. Ultrasonic sensor is used to measure the distance when mobile sensor node is moving. Blynk application is implemented to control mobile sensor node and it can also command desired movement of node deployment. NodeMCU from the mobile sensor node, motor controlling via phone, two laptops (one is for sensor data monitoring and the other is for network performance monitoring) are connected to WiFi via fixed router. This router is configured by IEEE 802.11n wireless LAN. The sensor data (distance measured) from the ultrasonic sensor is sent to ThingSpeak sever. NodeMCU transmits these sensor data to ThingSpeak via the router shown in Fig. 3.

And measured distance data is monitored with one laptop that is connected to WiFi via the router. The throughput and signal strength of the network is measured and it is monitored by using WinBox software shown in Fig. 4. From these data, the mobility pattern of this network is analyzed according to measured range information from ultrasonic sensor.

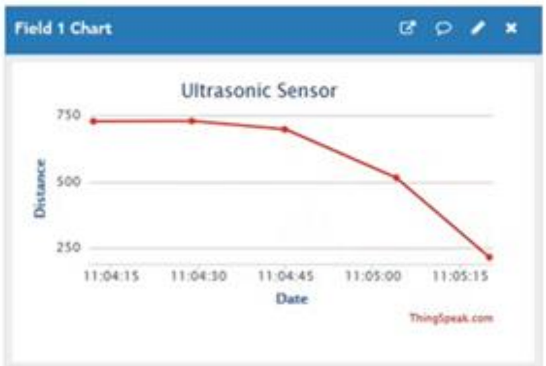

Figure 3. Monitoring moving distance on ThingSpeak

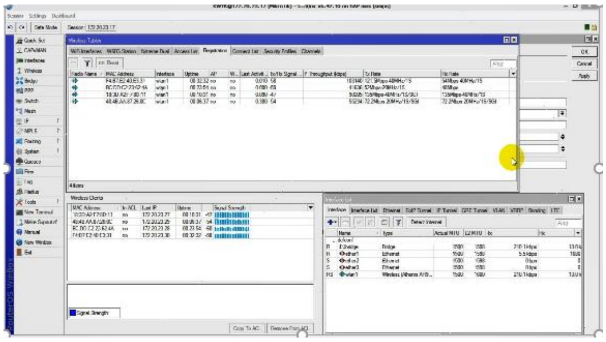

Figure 4. Monitoring throughput and signal strength

B. Testing Environment

In this work, 30 feet path from starting point to end point (at fixed router) distance is specified between fixed router and mobile sensor node. Testing environment 1 is less friction than testing environment 2 shown in Fig. 5. For these two testing, constant speed of vehicle is set as 10 cm/s. Ultrasonic sensor HC-SR04 can be used to measure distance in range of 2 cm-400 cm with accuracy of 3 mm. This sensor module is needed to trigger for signal transmission by using NodeMCU. NodeMCU reads arrival time between triggering and received echo. The speed of sound from ultrasonic sensor is around 340 m/s. When the system starts, sensor releases ultrasonic waves and gather return echo after hitting the obstacle. Based on round trip time, distance can be calculated.

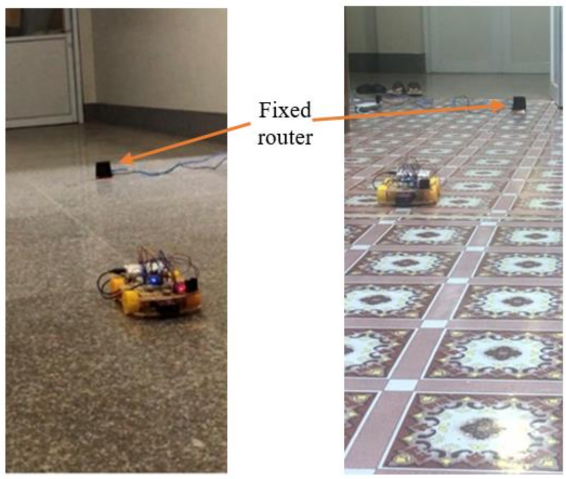

Figure 5. Testing in environment 1 and 2

C. Discussions

By analyzing test results within one-minute data collection, distance 1 from mobility of vehicle on the floor with less friction cannot be the same as actual distance. Distance 2 from mobility of vehicle on the floor with more friction can be approximately the same as actual distance shown in Fig. 6. In Fig. 7 and Fig. 8, signal strengths and throughput from two different testing are plotted with collected data time. Based on these results, changes in signal strengths and per-node throughput is approximately the same for two different testing. It can be seen that changes in signal strength and throughput are approximately constant in random direction mobility model. Reason for testing with constant vehicle speed in this mobility testing is to be focused on friction and frictionless environment. If variable speed is used in testing mobility, it is necessary to consider several parameters for suitable control technique and stability. Thus, this work was initially implemented and tested with mobile vehicle node without variable speed control program.

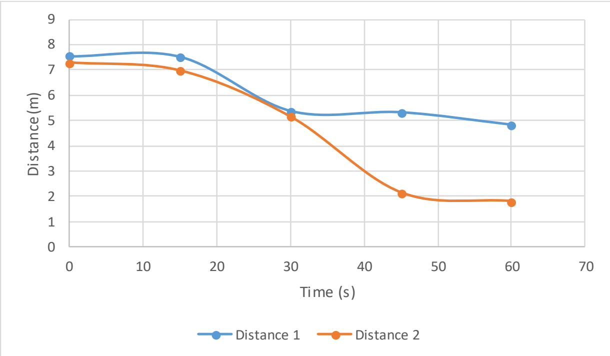

Figure 6. Results of moving distance in environment 1 and 2

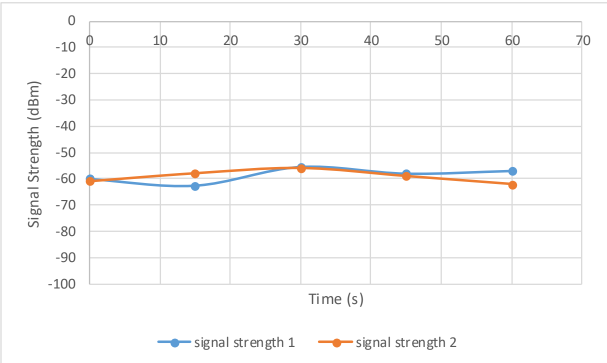

Figure 7. Results of signal strength in environment 1 and 2

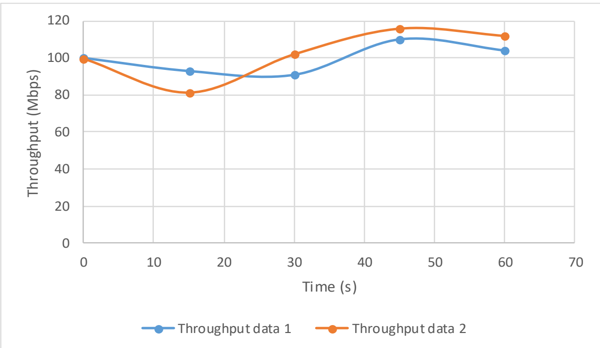

Figure 8. Results of throughput in environment 1 and 2

Based on measured results, per-node throughput changes gradually with distance except at initial start and final stop of mobile vehicle shown in Fig. 9 and Fig.10 in testing of two environments. The throughput at each distance seem nearly the same because vehicle mobility is stable in limited small range. Signal strength is almost stable with time and distance for two environment shown in Fig. 11 and Fig. 12. In this case, vehicle control is needed to consider for stable motion along defined path. It can be seen that network throughput may be affected by measuring moving distance collected from ultrasonic sensor equipped with moving vehicle in WiFi network. The IEEE 802.11n support a maximum theoretical throughput of 600 Mbps. But some routers can support theoretical maximums of 150, 300 or 450 Mbps depending on their configuration. The measured throughput from two different testing is in the range of 80 to 120 Mbps. It is lower than maximum theoretical throughput. This would be occurred when there will be some factors such as interference, packet delay and network workload.

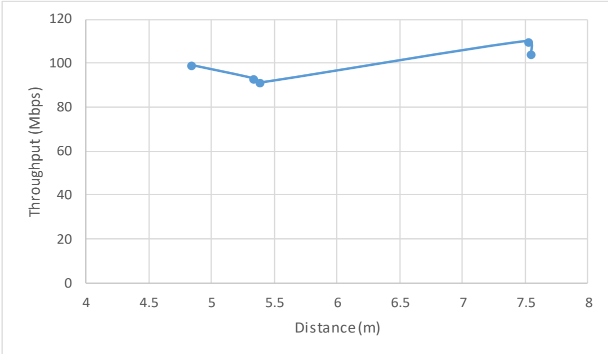

Figure 9. Plotting throughput versus distance for environment 1

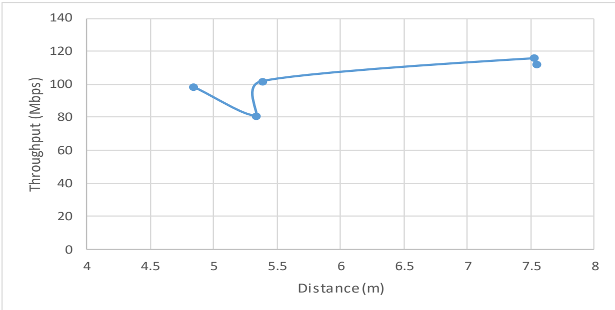

Figure 10. Plotting throughput versus distance for environment 2

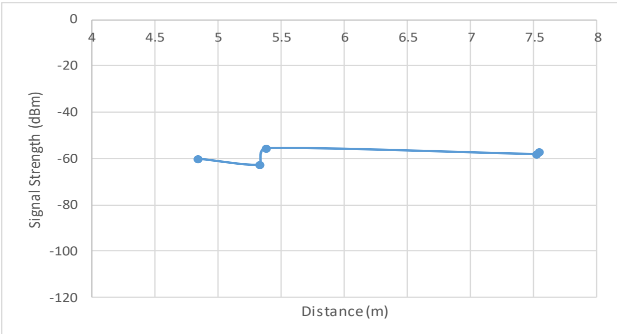

Figure 11. Plotting signal strength versus distance for environment 1

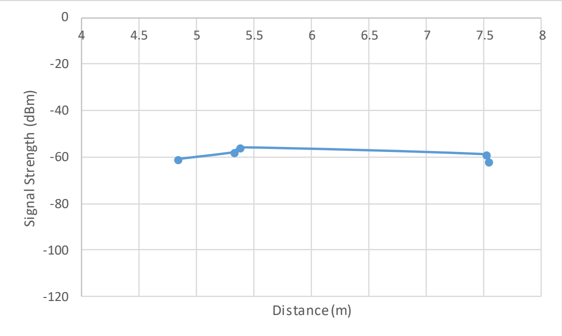

Figure 12. Plotting signal strength versus distance for environment 2

V. CONCLUSIONS

In this paper, range-based localization was used in measuring vehicle mobility in wireless sensor network. Measured range distance is obtained from ultrasonic sensor equipped with vehicle moving in WiFi network. The mobile sensor node was constructed with NodeMCU, WiFi module and ultrasonic sensor as localization finder. In vehicular mobility, all mobile sensor nodes can move arbitrarily fast. To maintain network performance for some constant time, experimental tests are done with constant speed of mobile sensor node. It is still needed to consider modifications for realistic vehicle mobility. Changing behavior of signal strengths and per-node throughput are presented and discussed on two different testing environments. Extended study on wireless mesh network by using many mobile sensor nodes can be applied on massive wireless IoT.

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