Real-time monitoring of GPS-tracking tractor based on ZigBee multi-hop mesh network

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***Abstract*-This research is a part of smart farm system in the framework of precision agriculture. The system was installed and tested over a year. The tractor tracking system employs the Global Positioning System (GPS) and ZigBee wireless network based on mesh topology to make the system communicate covering a large area. Router nodes are used for re-transmission of data in the network. A software was developed for acquiring data from tractor, storing data and displaying in real time on a web site.**

I. INTRODUCTION

Since the introduction of the global positioning system (GPS) in 1994, GPS-tracking has become widely used in many application area ranging from military [1], security system [2], logistics [3] and healthcare [4]. In agriculture, GPS tracking is going to become a revolutionary tool for modernization of agriculture today. GPS combined with other navigation technologies, such as laser path finding and accelerometer, has been a central part for agricultural vehicle guidance and farming automation. However, adoption of such system in developing countries is rare due to relatively high installation cost. In addition, most commercially available tracking and guidance systems are developed based on the agricultural infrastructure in the manufacturer countries that may require further customization for the imported countries. Hence, development of a low-cost version of this system domestically could be beneficial for the local farmers.

Tractor tracking is the most primitive functionality within the on-tractor precision agriculture. This function can be used per se to monitor the tractor uses in farm, which can lead to optimization of resources applied in the field. The technology allows the farm owner to know in real-time the current location of a tractor. Analysis of the tractor path helps farmer plan proper schedule, verify field operation and investigate driver's behavior. For example, in the large farm, farmer can use GPS tracking to verify gasoline use in one day or control and check worker activities.

Several research groups and agriculture equipment manufacturers have paid attention to this technology especially in the last five years. John Deere [5], a big brand manufacturer of tractor, has developed various types of navigation system in John Deere's tractors. Other tracking systems are mostly devoted to car. For examples, Jiewen Zheng [6] and his team developed tracking system for fresh food logistics and Miao Yu and Syed Mohsen developed the classification of farmer activity using RFID [7].

This research is a part of the Smart Farm Thailand project (www.smartfarmthailand.com) aimed to develop agricultural technologies for precision agriculture. The system has been installed and tested over a year. The tractor tracking system under this project employs GPS And ZigBee wireless network based on the mesh topology to allow the system to communicate within the farm area. Automatic routing capability theoretically allows this system to scale up to cover very large farm area. Data from the tractor is available on a web site in real time.

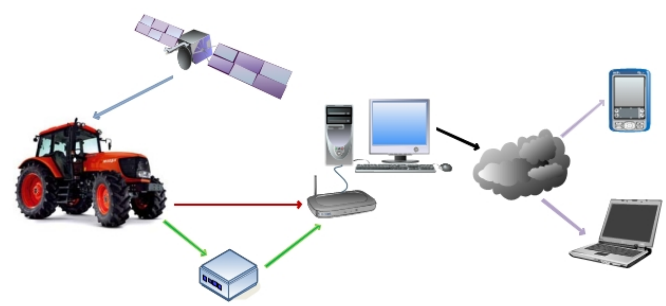

Figure 1. System architecture of the tractor tracking.

II. SYSTEM ARCHITECTURE

In Fig. 1, the tractor tracking system presented in this paper consists of the a GPS module, wireless communication based on ZigBee and data acquisition on PC. The position of tractor is updated every 1 second (1 Hz). GPS parameters are stored in a microcontroller and sent via wireless network based on ZigBee standard. The data can be either directly transmitted from the tractor to the coordinator node or via one of the repeater node, depending on the strength of the signal. The power source for GPS tractor tracking node is the tractor battery, whereas the router nodes are fed by solar cells charging on battery. The GPS tractor reports its current position and the engine status (either on or down) to the coordinator every one second. All data was archived in database and presented on the internet. Farmers can monitor their tractors anywhere and anytime.

III. HARDWARE AND SOFTWARE DESIGN

The whole system consists of three types of node. First is the end node as installed on tractor. Second, the router nodes installed on field to cover the farm area, acting as a repeater for communication between the tractor and the base station. The third type is the base , performing the duty to receive data and transfer them to a PC via a USB port.

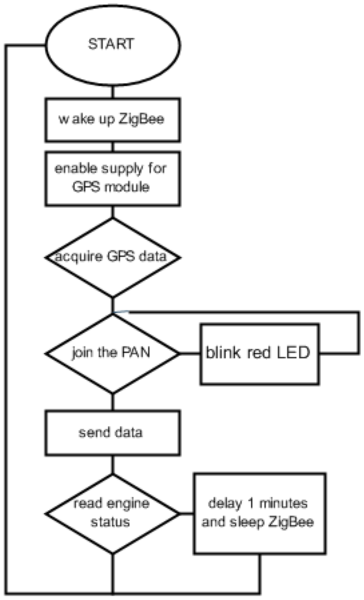

Figure 2. Block diagram of GPS tractor tracking node

A. *GPS tractor tracking node*

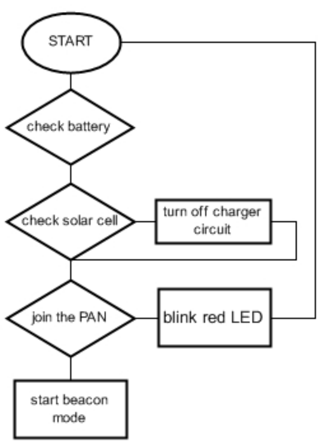

Figure 3. Block diagram of router node

A 16-bit high-performance microcontroller unit (MCU) from Microchip Inc, namely PIC24FJ128GA010, was used. MCU can acquire position from GPS module every 1 second (1 Hz). Ublox with 20 channel GPS receiver module was used. Data from this module comply with NMEA 1083 protocol. The data was decoded using GPRMC package of MCU. The information included in this package consists of the basic parameters of GPS data: latitude (north or south), longitude (east or west), ground speed, current date and time, course over ground and magnetic variation. The GPS tractor tracking node has 2 operation modes, as presented in Fig 2. MCU detects the engine status first in order to select the operation. The engine status is detected by the interrupt module in MCU, then used to decide and choose time to sleep. The GPS tractor tracking node was packed in a robust package to protect from water spray and dust and installed over the tractor radiator bonnet.

B. *Router node and coordinator node*

A microcontroller from Microchip, PIC18F45J10, was selected as a control unit for router node. This 8-bit high performance microcontroller is based on nano-watt technology. Each router node uses solar panel and re-chargeable battery to work as the power source. The microcontroller unit reads voltage indicator from the solar panel and the battery during the system start process and send AT-command to ZigBee module to check for the member node in personal area network (PAN). The router node can be programmed to save energy by using a cyclic sleep mode. Under this feature, microcontroller is shut down, except for the Zigbee being in a wake for incoming signal. This wake-on-demand function allows the router to save energy similar to the end nodes.

The receiver or coordinator node consists of an 8 bit microcontroller, real-time clock, ZigBee with coordinator scenario and USB-serial converter chip. The MCU features 1 megabytes flash memory and 2 UART modules for connecting with ZigBee and other one connecting with computer via USB-to-serial module. The real-time clocks capture current data while receiving position data in the field via the ZigBee networks. The data from every node are stored in the memory of MCU and subsequently transferred to a computer by UART every 2 minutes.

Figure 4. installed node with 10 dBm antenna and assembled board

IV. ZIGBEE WIRELESS NETWORK

ZigBee wireless network can operate in a wide range of environments and provide advantages in cost, size, power, flexibility and distributed intelligence compared to wired technologies. A ZigBee network can adopt one of the three topologies: star, tree or mesh. In this system, the network topology of multi-hop mesh is adopted to enhance the communication, because of reliability and network stability. The Xbee-PRO RF module used in this work is a ZigBee/IEEE 802.15.4 submissive solution for wireless networks. Basic and advanced configuration can be implemented using simple AT commands (Hayes command set) or API function. In this work, AT commands are used to communicate with MCU. According to the datasheet specification, it uses 60 mW (18 dBm), 100 mW EIRP (Equivalent isotropically radiated power) power output (up to 1.6 km range).

A major problem of Zigbee is the communication range. In order to communicate data for a larger area, the router node was installed at a suitable location to be on alert for repeater data. Xbee modules from DIGI provides an AT-command set for controlling and getting some parameter from module. For example, ATND is node discovery in the personal area network (PAN). In this study, our teams installed 2 router nodes in the vineyard and program a scenario for the repeater to re-transmit data from the GPS tractor node. In a network, if a node cannot directly contact the coordinator station, the message may be forwarded over multi-hops. By auto configuration set up, the network could continue to operate as nodes are moving to join with some router node. Although the multi-hops mesh network require reliability and high stability, the router node uses power from solar cell and rechargeable battery.

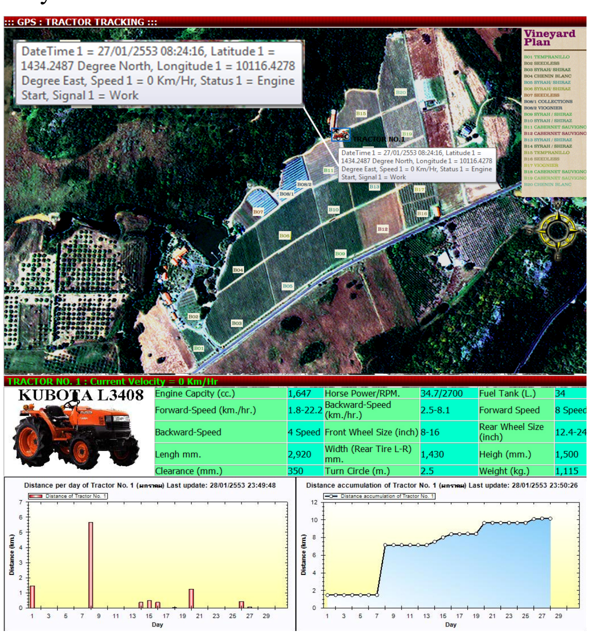

Figure 5. Public information on website.

V. RESULT

The real-time monitoring system is displayed on the website www.smartfarmthailand.com, which shows the real-time position of tractor. The GPS tractor tracking system was installed at Granmonte vineyard, Kaoyai. The data shown on the web consists of latitude, longitude, ground speed, current time and date of the lastest data package, engine status and satellite received status. Data can be poped up when mouse is moved over the tractor icon. The tractor was animated on an aerial photograph with estimate position equivalent to the real position (see Fig 5).

The distance of tractor was kept in a database in computer. Current data are updated every 2 seconds and graph is plotted to show the distance accumulation for each day. According to Fig. 6, data in December 2009 was shown.

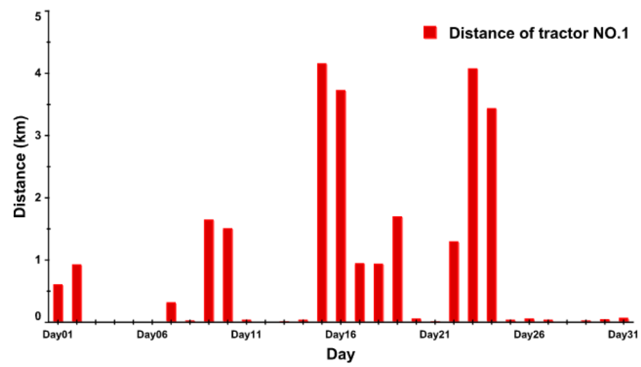

Figure 6. Distance in each day.

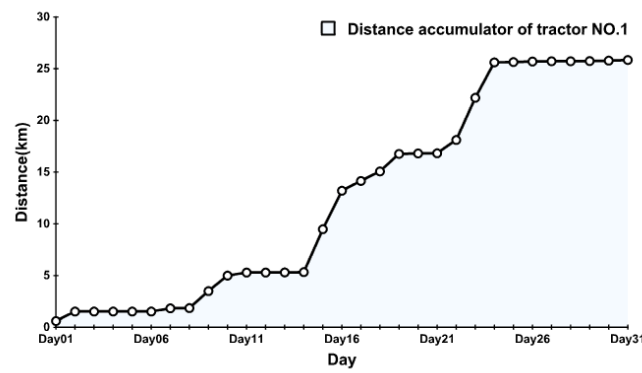

Figure 7. Accumulate of distance information.

Fig 7 shows incremental distance of tracked tractor in December 2009. This information can help farmer summarize period of activities for reducing and managing the gasoline use.

VI. CONCLUSION

In this paper, we have proposed a GPS tractor tracking system, using ZigBee multi-hop mesh network for data communicate in the farm. This work is carried out in framework of precision agriculture. The system was installed and tested over 1 year at Granmonte vineyard which covers an area of about 70 rai. The system can help farmer for managing and reducing the resources for tractor or other vehicles in the farm. Data and information of distance in real time and distance accumulation per day and month are kept in database and accessible freely to the public. http://www.smartfarmthailand.com/granmonte/gps.html

In the future, we plan to integrate other related devices such as soil and plant sensors, spraying devices, lawnmower etc. In order to select the most suitable farming activity, farmer can plan the activities in each day and arrange the most significant activities to control the gasoline and managing the spending of time. Farmer can installed more one nodes into this system, which can be useful for information processing and for intelligent tracking management.

ACKNOWLEDGMENT

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