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Performance of short and long range wireless communication technologies in construction

Payam R. Zekavat [a], Sungkon Moon [a], Leonhard E. Bernold [b]

[a] School of Civil and Environmental Eng., UNSW, Kensington, NSW, Australia
[b] Department of Civil Engineering, Universidad Tecnica Federico Santa Maria, Valparaiso, Chile

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ABSTRACT

The ever increasing complexity of construction projects asks for improved communication and automated data collection supported by continually improving electronic tools. Advances in information technologies enable us to link critical resources on construction sites, such as trucks and cranes, to the project website creating many opportunities to drastically improve productivity, safety and quality. While the use of electronic equipment is nothing new in construction, no model exists to integrate them into one unified framework. This paper presents a wireless site-network concept consisting of information hubs enabled to automatically connect data sinks with sources supported by software agents. Included in this paper is the discussion of a mobile information hub, the *e*CKiosk, enabled to connect the work crew electronically to the project network while collecting automatically live "as-built" data. It begins with a review of long range wireless as the basis for designing a robust Agile Site Communication Network (*ASCNet*). Site experiments with short range wireless conduits and embedded RFID tags showed that they are able to provide information far beyond an identification number. While wireless technologies are poised to open totally new avenues to manage construction, more field-tests are needed to establish a solid knowledge base to create a pervasive network for the dynamically changing building site.

1. Introduction

Reports and papers continue to highlight the effect of poor communication in construction. It's felt that the "nerve system" of management on construction site is slow and its reach limited while lacking suitable communication media [1]. The long overdue adoption of the Building Information Modelling (BIM) standards advances only slowly into the actual construction where the high cost of poor interoperability between design and construction software still remains [2]. One critical area of weak communication is the "space" between the already networked main office and the work-front. According to Nuntasunti and Bernold [3] "the digital format of wireless communication opens the possibilities to link sensors and devices that are mounted on the equipment, machines, and tools to the integrated wireless site (IWS)."

Despite the rapid developments in wireless technology designed for high performance in rough environments the manual paper-based dissemination of drawings, work and change orders is still the state-of-the-practice in construction. In particular, wireless devices utilizing the IEEE 802.11 b and g protocols are "robust" enough to link the many construction work crews, electronic sensors and other devices in real time to the Project Communication Network (PCN) presently mainly used by designers and upper level project managers. Illustrations of recent developments include: a) WiFi, b) ZigBee, c) Wireless Sensor Network (WSN), d) Radio Frequency Identification (RFID), e) sensor-equipped construction equipment, and f) global data standards and high transfer rates up to 600 Mbps from IEEE 802.11n. One example of a ruggedized equipment data acquisition system utilized in construction is the Measurement While Drilling (MWD) that integrates several sensors (i.e. accelerometer, magnetometer, temperature, vibration) applying a telemetric communication system [4]. Real time measurements from drill bit are continuously communicated to the surface in support of steering resulting in faster, safer and more accurate drilling. With the provided data, the operator is able to monitor the performance of all important components of the machine on a high resolution monitor screen. In addition drilling data are collected to create live "as-builts" related to the sub-surface. Still the MWD's feedback data is not shared. Connecting this "island of information" to other equipment or to the PCN, however, requires the hurdling of several obstacles; a) integration of communication hardware, b) providing power, c) interoperability between systems, d) data security, e) ownership of data, f) user-friendliness, g) cost, and h) ruggedized housing against dust, heat and rain.

The construction supply chain is another area that has applied wireless technologies. Many suppliers take advantage of RFID and GPS on a regular basis to locate their resources. So far, their use is limited to tracking containers, trucks and pieces of material. This leaves many opportunities to reduce present process wastes such as resource idleness, time for re-handling and searching for missing material which are mainly caused by poor supply control. In order to create a seamlessly integrated monitoring network covering the entire supply chain, it is necessary to

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improve our understanding of the performance of wireless devices and their electromagnetic transmissions on construction sites. For example, Tzeng et al. [5] pointed out that distance, relative angle, location and response time are the most critical factors in determining RFID tag's readability rate, vital to its successful use in construction.

This paper will discuss the results of field testing several wireless methods after introducing a site communication network capable of linking mobile information hubs to the PCN.

2. An Agile Site Communication Network (*ASCNet*)

Most construction sites receive their resources by road transport. To plan a more efficient unloading process the exact arrival time, the size of the vehicle and its load have to be available. At present, such upfront data is not readily obtainable as the various sources are still operating as "islands of information". Fig. 1 offers a model designed to create communication links between essential data sources and sinks, constituting a smart construction site [6–8]. In the demonstrated hypothetical situation, the *ASCNet* includes the main resources involved in placing concrete for a slab such as GPS embedded concrete supply trucks, concrete pump and a tower crane. Although the GPS data is used by suppliers to manage their hauling fleets, the tracking data would be invaluable information to the site. For instance, projected arrival times of the supply trucks could be instrumental in managing the placement crew thus minimizing idleness of both truck and crew. The essential enabling tool is the use of a mobile electronic information hub as a reliable access point for various devices.

Each work crew is assigned its own hub, in operating similar to a mobile-phone, linking the work-front to the PCN. Fig. 1 indicates that a wireless access point (WAP) provides the coverage with radio signals using one of the 2.4 GHz IEEE 802.11 protocols. Of course, the constantly changing construction site and the moving equipment create many interferences leading to electronic noise and, as a result, to abrupt signal loss. Hence, the design of a reliable WiFi network depends on a deep understanding of potential attenuations that need to be compensated by installing signal repeaters in a proactive manner.

Fig. 2 shows the new communication hub interfaced with other modules and the *ASCNet* and a wireless sensor network that facilitates data acquisition for automatic documentation. At the same time, sensors embedded in the operation are able to collect data of critical measures (e.g., pressure) about the work in progress and, supported by software agents, sound the alarm about unsafe developments or delays on the supply route. If designed effectively, the communication hub serves as a proactive feed-forward control to avoid costly process wastes and unacceptable output quality.

Interoperability of the selected tools consisting data hubs able to provide, collect and transceive data, RFID readers, electronic sensors, cameras, etc. is essential in order to supply key information in the recognized complex communication pattern. In summary, the smart site is functional only if different pieces of hardware are compatible to secure the required wireless conduits. The remaining part of the paper will discuss the pretesting of physical and communication layers followed by the outcome of field-tests.

3. Pretesting of system components

The main challenge in establishing a strong wireless backbone to support mobile information hubs is the creation of a reliable communication network providing sufficient signal coverage throughout the entire site. As mentioned earlier, the dynamics of a construction site threaten the availability of signal strength at critical spots. Of course, utilization of embedded RF tags brings in different difficulties as the RF signals interact with fresh concrete with high water content, hardened concrete as well as steel reinforcing bars. The following section introduces the prototyped information hub followed by the results of systematic studies on the performance of each wireless technology.

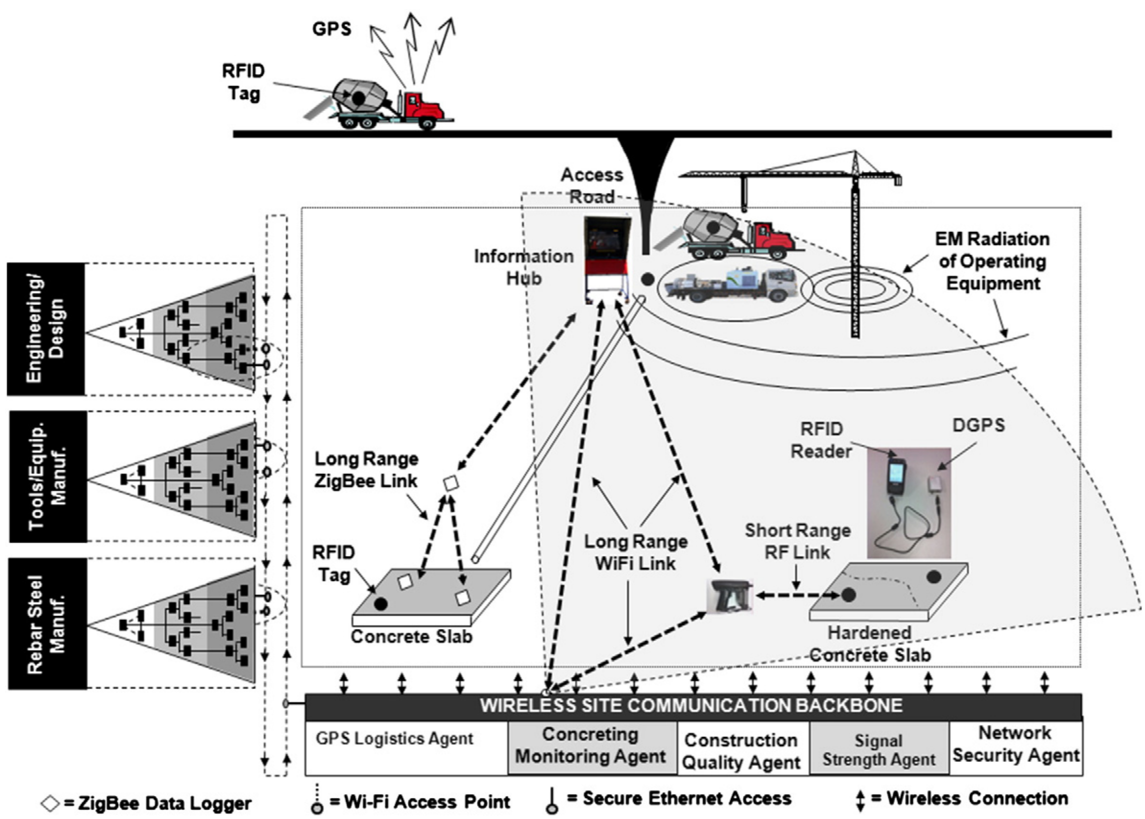

Fig. 1. Agile information network for construction.