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A FRAMEWORK FOR RFID ENABLED MATERIAL MANAGEMENT FOR CONSTRUCTION INDUSTRY

Naman N. Borda[1], Dr. Jayeshkumar R. Pitroda [2], Dr. Jagdish M. Rathod[3]

[1]*Construction Engineering and Management, Civil Engineering Department, BVM Engineering College*
[2]*Associate Professor, PG Coordinator Construction Engineering and Management, Civil Engineering Department, BVM Engineering College, Vallabh Vidyanagar, Gujarat*
[3]*Professor, Electronics Engineering Department, BVM Engineering College, Vallabh Vidyanagar, Gujarat*

Abstract – This research paper developed a framework for integrating RFID based material management to improve on site material tracking processes. In order to develop the framework, a literature review on material management problems on site and implementation of RFID technology in construction industry were conducted. Case studies were also conducted to examine material management practice on site and problems faced during material management. An initial study exposed that there is a potential to improve the use of RFID technology to mitigate the problems arises during management and tracking of material on site. This research paper concludes the finding from the case studies for developing a framework for real time material tracking on construction site to improve project delivery process.

Keywords – Construction Project, Material Management, Material Tracking, Radio Frequency Identification (RFID)

I. INTRODUCTION

The major problems that impact the project performance is the inappropriate handling of materials during construction activities. Due to improper management and handling of construction material on site affect the performance of construction project. There are many problems that affect the performance such as insufficient storage areas, improper handling and management of construction materials, late delivery of material to the construction site. Many authors also highlighted material management problems such as, inappropriate storage, need of large storage capacity, logistic difficulties.

There are number of approaches available to mitigate material management problems such as, appropriate planning of material, Just In Time (JIT) concept to resolve the problems.

Usually, emerging technologies such as Radio Frequency Identification (RFID) and wireless technology are not efficiently used in the material tracking. There is also insufficient support for the tracking and management of material for operational efficiency in inventory management on construction site. It is expected that RFID can be beneficial in reducing paper based requirement and can also be integrated with different application such as project management system to make tracking and management of materials easier and faster.

The technologies that can be used for material management and tracking on construction site are described. After that paper presents the case studies that were undertaken to find out material management practice on site and problems faced during material management and tracking on construction site. After discussion of case studies, framework was developed for RFID based material management for real time material tracking on construction site.

II. TECHNOLOGIES FOR MATERIAL TRACKING

A. RFID Technology

In this RFID technology is described in brief that how it works and components of RFID system.

1) Working of RFID Technology

There are two primary components of an RFID system as shown in figure 1. The whole RFID system requires the tags and the reader including an antenna to be operated. The RFID tags or transponder are normally located on the object or people to be identified. The RFID reader or interrogator provides, read and write/read facilities through a fixed or mobile reader to communicate data to and from the tags. The following section explains further the components of the RFID system, the tags, readers and antenna.

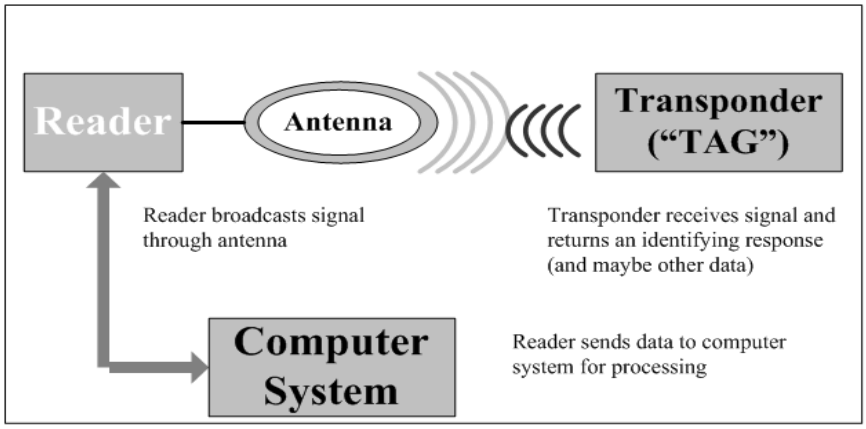

Figure 1 Working of RFID Technology

2) Components of RFID System

The following table 1 shows the components of RFID system and its function during the operation of RFID system.

Table 1 Components of RFID System and its Functions

RFID Components	Details
Tags (Transponder)	Tags or transponder are normally located on the object or people to be identified.
Reader	Reader interrogator provides, read and write/read facilities through a fixed or mobile reader to communicate data to and from the tags.
Antenna	Antenna is the conductive element that enables the tag to send and receive data

B. Application of Other Technologies in Material Tracking

The following table 2 shows previous research regarding successful applications of technologies such as Radio Frequency Identification (RFID), bar-coding, Global Positioning System (GPS), Geographic Information System (GIS), Ultra-Wide Bands (UWB), Personal Digital Assistant (PDA), and General Packet Radio Service (GPRS), Laser Distance and Ranging (LADAR) and others in various field of application in construction especially in materials tracking.

Table 2 Different Application of Technologies in Material Tracking

No.	Application
1	Using RFID and GPS to track precise movement and location of materials on construction site and in lay-down yards
2	Using RFID to identify of accurate location of underground assets
3	Using bar-coding, RFID and LADAR to automate data collection from highway construction sites
4	Use RFID and GPS in identification and localization of engineering components on industrial sites
5	Use RFID, PDAs and laptop to facilitate construction materials management and solve materials management problems
6	Use UWB, RFID and GPS for asset tracking and safety assurance
7	Use RFID in information lifecycle management for material control on construction sites
8	Use RFID to track tools and store pertinent operation and management data regarding the tools on construction job sites
9	Using RFID, GPS and GIS for ubiquitous tracking and locating of construction resources
10	Use RFID for real-time monitoring of material in construction sites
11	To investigates a new approach for integrating RFID, GPS and GPRS for real-time data collection in construction

III. RESEARCH METHODOLOGY

A multiple-case research strategy was adopted for data collection. It was suggested that the data from the case study could be collected by questionnaires and interviews. However, the interview is one of the most significant sources of information for the case study. Therefore, data collection on these case studies has primarily been by interviews. Interview questions were organized under broad headings including (1) Key problems in materials management practices, (2) Approach to addressing problems, (3) ICT implementation, (4) Emerging technologies, and (5) Materials tracking systems.

Data analysis involved both single case and cross-case analyses. Single case analysis was conducted to produce individual case reports in order to gain the information of current practices, problems and ICT implementation in materials management practices. This allows the unique patterns of each case to emerge before pushing towards

generalized patterns across cases. Cross-case analysis is used to make a comparison of the elements of analysis collected between the case studies.

IV. CASE STUDIES

Background information on four construction projects involved in the case studies are presented in table 3.

Table 3 List of Construction Project in Case Studies

Case Study	Type of Project	Respondent	Experience (Years)	Cost (□)
A	Textile Building Project	Site Manager	05	1500 crore
B	Railway Station Development Project	Project Manager	27	294 crore
C	Institutional Building Project	General Manager	23	20.25 crore
D	Metro Rail Project	Planning Engineer	02	198 crore

A. Case A: Textile Building Project

1) Overview of Project, Key Problems and Approaches to Address Problem

Project A involve the construction of a textile building with a total cost of □ 1500 crore. The major problems faced by this project in management of material were as follows.

1. Late Delivery: This was very often problem in the supply of material to the construction site.
2. Logistic Problem: Due to inadequate storage space on the construction site, material having to be stored in a separate location.
3. Site Access Problem: Construction site has 3 road at its periphery, so the traffic congestion was very high and very difficult for any material delivery vehicle to enter the site.
4. Late Decision by Client: Owner/Client was frequently changes the design of the construction or specification of the material, and taking so much time for decision.
5. Design Changes: Frequently changes in the design of the project causes the error at material procurement and material management.
6. Tower Crane Location: There were two tower crane, but due to lake of experience of tower crane, fixing of the location of tower crane was major problem.

On such a large and complex project, there was a vital need to have a strategy to handle the above problems. In order to overcome the logistic problems, late decision by client and design changes, regular discussion and coordination meetings with all were undertaken. Weekly meetings has been also arranged between contractor and client and sub-contractor to discuss the problems arises and how it was overcome. In order to overcome site access problem, one time slot has been fixed during night time to delivery of material.

2) ICT Implementation, Emerging Technologies and Material Tracking System

This construction project makes use of basic ICT tools such as 1. Email system. 2. WhatsApp Mobile Application. The use of Email system and WhatsApp in this construction project was to facilitate purchasing activities and storing all material information. Ordering of material was done by Email system. This construction project didn't use any emerging technologies to facilitate tracking of material on construction site. Site manager was not aware of the importance of any emerging technologies for automated management of construction material. In this construction project, no technologies were used for tracking of material on site. Manual methods were still used to facilitate tracking of material. Delivery confirmation and stock of material also check by manually.

B. Case B: Railway Station Development Project

1) Overview of Project, Key Problems and Approaches to Address Problem

Project B involved redevelopment of railway station of Gandhinagar. Total cost of project is 294 crore. The most significant challenges faced by the project manager were as follows.

1. Late Delivery: Delivery of material on the construction site is affected by delays and time constraints due to train operation.
2. Design Changes: In this construction project many time design of the main building has been changed. Due to that material procurement and storage problems arises.
3. Material Specification: As describe above due to change in design, specification also get changes for some particular material. So new purchase order has to be made and old material has to be return.
4. Inadequate Storage Space: Due to limited area of the construction site, material storage was the major problem.

5. Limited Working Area: Due to working condition of railway station, very limited working space was given to the contractor. In that they have to store the material as well as have to done construction activities.

There were several approaches to overcome to all the problems describe above. In order to overcome inadequate storage space and limited working area problem, they have establish one separate yard for storage of material near construction site. Limited material were brought to the site as per the construction activities. In order to overcome design change and material specification, Quick Respond were given to that and quick meetings were arranged and find solution of that. The Railway regulation and time permission for the operation provided by the Railway Control Authority should be followed.

2) ICT Implementation, Emerging Technologies and Material Tracking System

There were some basic ICT tools used on this construction project as follows. 1. Email System 2. Microsoft Excel 3. SAP ERP. An Email system was used in purchasing activities and Microsoft Excel to facilitate in storing all material information and as database system. The role of the Email system was only for communication purpose. SAP ERP was used to facilitate the planning of material procurement and tracking of material on construction site. No emerging technologies were used in this construction project. But after interview, interviewee realized that, there is a huge impact of these type of technologies on material management and tracking of material on construction site. In this construction project, manual practices were used to facilitate material tracking activities.

C. Case C: Institutional Building Project

1) Overview of Project, Key Problems and Approaches to Address Problem

Project C involved the construction of the institutional building for an academic purpose with a total cost of the project 20.25 crore. The most significant challenges faced by the project manager were as follows.

1. Site Access Problems: Construction site was in college campus, so it was very difficult to access the site during academic hours.
2. Storage Area: As the site was in the college campus, very limited area was provided by client to construct the building. So storage of material was difficult for them.
3. Late Decision by Client: Many times client was unable to deliver the perfect decision to the contractor about the specification of material, due to that contractor was unable to purchase the material in advance before construction of particular activity and it results into time overrun and cost overrun.
4. Material Specification: As describe above, client often changes the specification of material during construction.

Many approaches were there for overcome the problems describe above. Site access problem was overcome by providing separate route to the construction site. By this material delivery problem also solved. Storage area for material was overcome by providing separate storage yard near construction site. Frequently meetings were arranged between contractor and client to overcome the late decision problem and material specification problems.

2) ICT Implementation, Emerging Technologies and Material Tracking System

Generally, this project used only basic tools of ICT on construction site such as. 1. Email system 2. SAP ERP. An Email system was used in purchasing activities and Microsoft Excel to facilitate in storing all material information and as database system. SAP ERP was used to facilitate the planning of material procurement and tracking of material on construction site. This project did not use any emerging technologies to facilitate materials tracking on the construction site, but the site manager was aware of the importance of emerging technologies for automated materials tracking. In this project, manual methods were still used to facilitate tracking of material for the purpose of delivery confirmation and inventory checking/management.

D. Case D: Metro Rail Project

1) Overview of Project, Key Problems and Approaches to Address Problem

Project D consist construction of new railway line for metro and metro station. Total cost of the project was 198 crore. In managing this project, the planning engineer identified several problems relating to material management as follows.

1. Late Delivery: This project consists construction of bridge for metro line on existing road. The traffic of vehicle on the road was very high. So there was very much difficulty for bringing material at scheduled time.
2. Site Access Problem: As describe above, road traffic was very congested. So transportation of material to the site was very difficult and at pick hours of traffic, no permission granted for transportation of materials.

3. Material Damage: Construction of bridge consist precast segment. Pre cast segment was prepared near the construction site and from that they were transported to the construction site. Sometime during transportation, pre cast segment get damage.
4. Project Site Challenge: As the project was going on existing congested road, many challenges need to be faced during transportation operation and construction operation.

The main contractor conducted meetings every day to coordinate the subcontractor's daily activities. The biggest concern with respect to logistics was bringing large material and precast segment onto the construction site, which was on the very congested road. For material storage problem, their storage yard and pre cast segment construction site was separated but nearer from actual construction site.

2) ICT Implementation, Emerging Technologies and Material Tracking System

Generally, the material management on this project was supported by several ICT tools, including, E-mail System for the communication and purchasing order of material. Fax System for the purchasing activities for construction materials. Through this project the interviewee realized the importance of using emerging technologies in developing their materials management practices for tracking materials. This project utilized manual methods to facilitate materials tracking activities on the construction site.

V. DISCUSSION AND ANALYSIS

The result on cross case analysis within case studies is summarized in table 4. Generally, the findings from case studies reveal that the major problems in term of materials management activities relate to constraints on storage areas, site logistics with regards to materials handling and distribution, and also with ordering and delivering of materials to the construction sites. The initial feedback identified the issue of space problems which had been experienced by all construction companies interviewed. The logistics problems are caused by single access to construction sites, surrounded by public infrastructure such as schools and railways, congestion of materials' vehicles during peak time, and regulation considerations.

Basic ICT tools such as fax machine and excel spreadsheets are used to support purchasing activities in many construction projects. However, there is inadequate use of modern ICT tools such as RFID to assist with automatic identification and tracking of materials. There is also a lack of robust ICT tools which can integrate materials, labor and plant into one system. In order to improve efficiency and effectiveness of handling materials, it is important to change from manual practices to automatic practices and also provide real-time information. As a result, this research will develop a system to integrate RFID-based materials management with resources modelling in project management systems to improve on-site materials tracking and inventory management on construction projects. The next section presents the outline features of a framework for a real-time materials tracking system.

Table 4 Cross Case Analysis

Element of Analysis	Case A	Case B	Case C	Case D
Material Management Problems	1. Late Delivery 2. Logistic Problem 3. Site access Problem 4. Late Decision by Client 5. Design (Drawing) Change 6. Tower Crane Location	1. Late Delivery 2. Design (Drawing) Change 3. Material Specification 4. Inadequate Storage Space 5. Limited Working Area	1. Site access Problem 2. Storage Area 3. Late Decision by Client 4. Material Specification	1. Late Delivery 2. Site access Problem 3. Material Damage 4. Project Site Challenge
Approaches to Addressing Problems	1. Constant Monitoring 2. Weekly Meeting	1. Quick Respond 2. Provide enough storage and monthly stock checking	1. Provide enough storage 2. Separate access to the site	1. Everyday Meeting 2. Separate Storage Yard
ICT Implementation	1. E-mail System 2. WhatsApp Application	1. E-mail System 2. Microsoft Excel 3. SAP ERP	1. E-mail System 2. SAP ERP	1. E-mail System 2. Fax System
Use of Emerging Technologies	1. No	1. No	1. No	1. No
Materials Tracking System	1. Manual	1. Manual	1. Manual	1. Manual

VI.A Framework For Real Time Material Tracking

The development of the real-time materials tracking process is based on the findings from the literature review and case studies. It is shown that it is important to change from manual to automatic processes and that there is potential to employ RFID to facilitate materials management on construction projects. An integrated approach for real-time materials tracking to provide an intelligent system is therefore proposed. The development of a framework for a real-time materials tracking system is intended to improve the overall process of materials management on construction projects. The framework for a real-time materials tracking system consists of the following.

1. Material Delivery: This stage involves the tracking of the materials delivery and delivery status at the construction site. The RFID tags attached to purchase materials are detected by a portable RFID reader during delivery at the entrance of the construction site. The materials delivery and delivery status information will be written to the tags and recorded in the database. This stage also involves the integration with the resource modelling in the work program so as to check the use status of specific materials.
2. Material Storage: This stage tracks the materials and identifies the availability of the storage area at the construction site. It is also recorded and verifies inventory utilization during taking in and out of materials from the storage area. This requires the integration with work program in order to identify specific materials for related work tasks.
3. Materials Use: This stage is required for tracking the materials used in the construction project. The work program provides the status of materials to be installed for specific work tasks.
4. On-site Control Centre: The site office acts as an on-site control center and will be involved in collecting and analyzing all the materials information in the database.
5. Report Transmission: The main office will be involved in receiving all the material information from the site office to generate the information required to produce reports.

The components of the real-time materials tracking system rely on the use of emerging technologies such as RFID as depicted in figure 2.

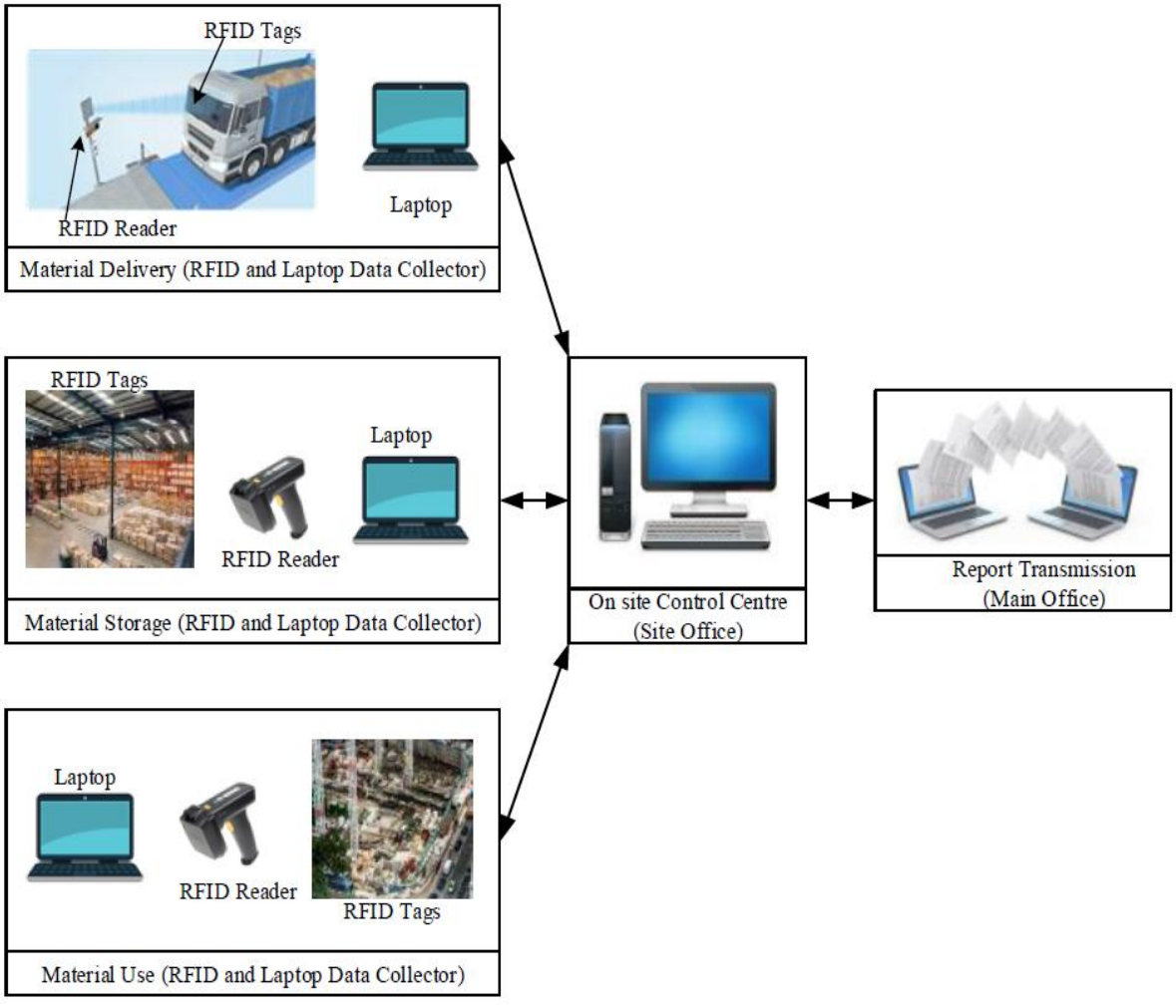

Figure 2 Framework for a Real Time Material Tracking System

VII. CONCLUSIONS

A total of four case studies had been undertaken in order to achieve the objectives of this study. That is to investigate the current issues and problems in materials management, and also the implementation of ICT and the potential of emerging technologies in overcoming the logistical difficulties on construction projects. Findings from the analysis show that many of the case study projects have similar problems with constraints of storage area. Handling and monitoring activities at site such as tracking of materials, is still facilitated by manual operations in all of the case studies, with a potential for many human errors and excessive paperwork. The use of sophisticated technologies such as bar-coding, RFID and wireless as recommended from the case studies to facilitate an automated materials tracking on construction projects can be implemented. Therefore, the framework of real-time materials tracking system as illustrated above has been developed to integrate RFID-based materials management with resources modelling in project management systems to improve on-site materials tracking and material management on construction projects. The development of the appropriate mechanism for data capture from RFID tags by RFID reader can store the information into the database and integrate with the work program.

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AUTHORS BIOGRAPHY

Borda Namankumar Nareshbhai received Bachelor of Technology degree (Civil Engineering) from Pandit Deendayal Petroleum University in 2017. At present, he is final year student of Master of Technology in Construction Engineering & Management from Birla Vishwakarma Mahavidyalaya, Gujarat Technological University.

Dr. Jayeshkumar Pitroda received his Bachelor of Engineering Degree in Civil Engineering from Birla Vishwakarma Mahavidyalaya Engineering College, Sardar Patel University (Vallabh Vidyanagar, Gujarat-India) in 2000. In 2009 he received his master's degree in Construction Engineering and Management form Birla Vishwakarma Mahavidyalaya Sardar Patel University (Vallabh Vidyanagar, Gujarat-India). In 2015 he received his Doctor of Philosophy (Ph.D.) Degree in Civil Engineering from Sardar Patel University (Vallabh Vidyanagar, Gujarat-India). He has joined Birla Vishwakarma Mahavidyalaya Engineering College as a faculty in 2009, where he is lecturer of Civil Engineering Department and at present working as Associate Professor from February 2018 having total experience of 19 years in the field of Research, Designing and Education. At present holding charge of PG Coordinator Construction Engineering and Management. He is guiding M.E. / M. Tech (Construction Engineering and Management/ Construction Project Management/ Environmental Engineering) thesis work in the field of Civil / Construction Engineering/ Environmental Engineering. He is also guiding Ph.D. students (Civil Engineering). He has published many papers in National / International Conferences and Journals. He has published nine Research Books in the field of Civil Engineering, Rural Road Construction, National Highways Construction, Utilization of Industrial Waste, Fly Ash Bricks, Construction Engineering and Management, Eco-friendly Construction.

Dr. Jagdish M. Rathod received his Bachelor of Engineering Degree in Electronics and Communication from G.E.C. Modasa in 1995. In 2005 he received his master's degree in Electronics and Communication from D.D.I.T. In 2011 he received his Doctor of Philosophy in (Ph.D.) Degree in EC Department with specialization in Microwave and Antenna from Sardar Patel University. He has joined Birla Vishwakarma Mahavidyalaya Engineering College as a faculty in 1997, where he is lecturer of Electronics Engineering Department and at present working as Professor. He has guided more than 104 student from U.G. He is guiding M.E. / M. Tech thesis work in the field of Wireless Communication, Antenna and Microwave. He also guiding Ph.D. students. He has published many papers in National / International Conferences and Journals. Ha has been awarded Best Teacher by BVM Engineering College in Recognition of valuable contribution and performance in Academic activities during the year 2011-12. He is life time member of India Society for Technical Education (ISTE), New Delhi. His field of interest are Electromagnetic, Wave propagation and Antenna, RADAR and Microwave Engineering and Wireless Communication.