RFID: Recent prospectus and commercial applications

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ABSTRACT

This paper portrays recent trends in Radio Frequency Identification (RFID) systems and its commercial relevance. RFID is one of the most researched and rapidly emerging technologies. With the recent technological advancements at International level, it is finding its application in various areas and has a bright future scope. Exemplary future applications and systems based on RFID and other technologies integrated with RFID are proposed in this paper.

We have discussed about applications, problems being faced by RFID systems & their limitations in other fields in the current era The commercial scope in the field of RFID manufacturing and research has been discussed along with its business prospectus. We have discussed about the hardware and software limitations that may be restricting or preventing its usage or feasibility in some fields or areas. We tried to depict some of the future enhancements that may be possible.

Keywords

Radio Frequency Identification (RFID), Wireless Sensor Network (WSN), Electronic Product Code (EPC).

1. INTRODUCTION

RFID is a major component of Pervasive computing. RFID technology is considered as "a key to automating everything" [26]. Nowadays, RFID and Wireless Sensor Networks (WSN) are used widely in pervasive computing environment [2]. RFID finds its use in the many areas including asset tracking, real time supply chain management and telemetry based remote monitoring [4]. RFID technology was used in World War II by army planes to distinguish enemy planes from allied planes through the use of radar [23]. RFID and similar technologies will play a vital role in future. There will be large wireless networks for communication and small wireless networks between different kinds of entities [5].

In section 2, we will discuss some of the latest trends in RFID. In section 3, we will discuss about the commercial and business prospectus of RFID, its market position, applications, limitations, solutions, challenges and future scope. In section 4, we have proposed some new techniques for RFID applications followed by a comprehensive discussion in section 5.

2. THE TREND

2.1 Radio Frequency Identification (RFID)

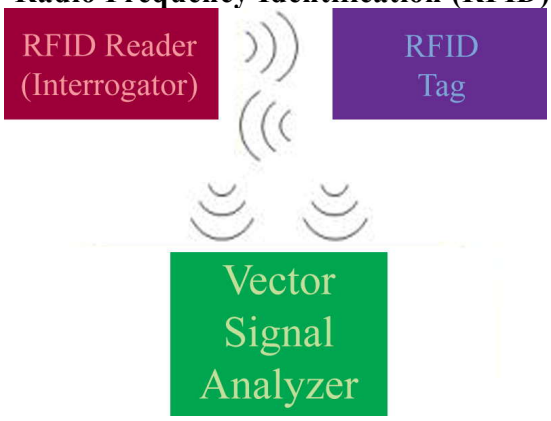


Fig.1 RFID system

RFID is a method for automatic identification of any object. RFID relies on storing and remotely retrieving information or data. RFID system basically consists of RFID tag, RFID reader and back-end database [12, 13]. RFID tags are used to store ID information of any object and RFID reader are used to communicate tags to remotely retrieve their ID. The technology is dependent on communication between RFID tags and RFID readers as depicted in Fig.2 and Fig.1.

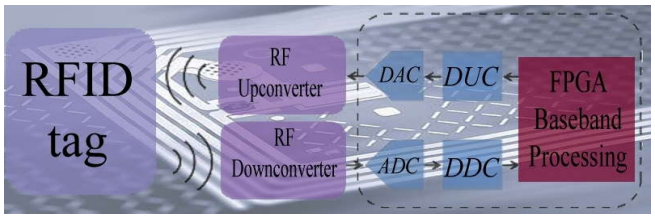


Fig.2 RFID system

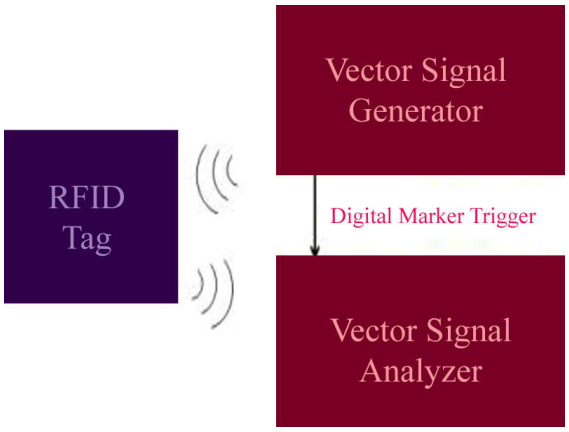
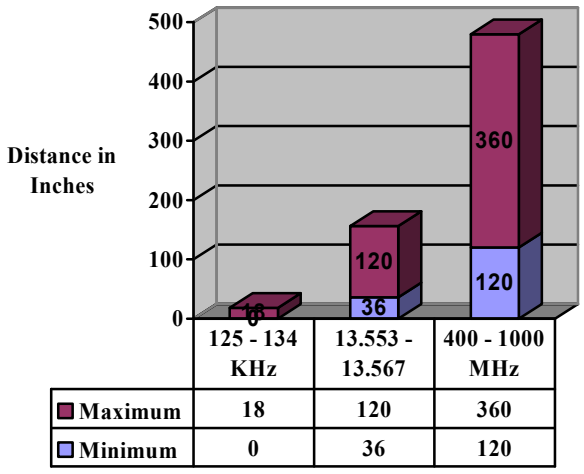


Fig.3. RFID system



	125 - 134 KHz	13.553 - 13.567	400 - 1000 MHz
Maximum	18	120	360
Minimum	0	36	120

Fig.4.

The range of the reader is dependent upon its operational frequency [16], as depicted in Fig.4.

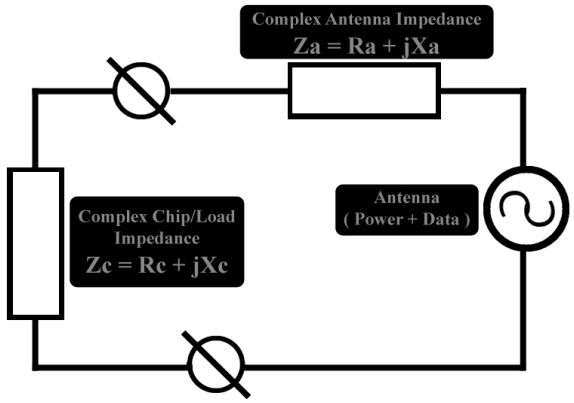


Fig.5.

RFID tag is a small device consisting of an integrated circuit and an antenna [15]. Tags can be incorporated into any device, object or living being for tracking and identification. The integrated circuit is used for modulating / demodulating radio frequency, processing information and other purposes. The microchip can be as small as 0.4 mm^2, comparable to a grain of sand [41]. The antenna is used for receiving and transmitting radio signals. The data stored in a tag may vary from 32 Bytes to 1 MegaByte depending upon the type and design of tag [14]. In Fig.5 the thevenin equivalent circuit of an RFID tag has been shown where Za is complex antenna impedance and Zc is complex load/circuit impedance [50].

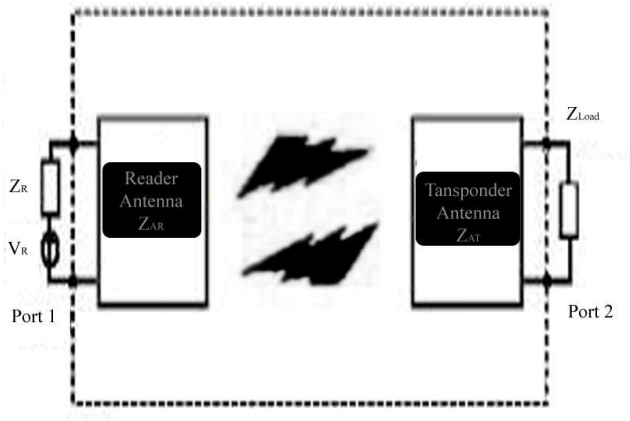


Fig.6. [51]

2.1.1 *Active RFID tag*

Active RFID tag is a tag that contains a battery within them [15]. The battery may be used to fully or partially supply power to tag's circuitry and antenna. Some tags may even be connected to external power source [to be cited]. Batteries may be replaceable for long functioning of the tag. Active RFID may have many capabilities such as capability to initiate communication, perform diagnostics and perform independent monitoring and control. It also has comparatively higher bandwidth and communication range. They may even have autonomous networking which allows them to select the best communication path by themselves. Active RFID tags may have a range up-to 100 meters and their advantage over passive tags is that they can also act as sensor node to record or monitor environment data and can have a temperature sensor and other sensors on them [7]. Other advantages are Long range and sensor integration capabilities. Besides that it has got some disadvantages like Limited lifetime due to dependency on battery, their high cost, costly maintenance if batteries need to be replaced, their larger size and elevated misreads due to battery outrages.

2.1.2 *Passive RFID tag*

Passive RFID tag is a tag that does not contain battery instead it uses radio waves for its energy needs. The reader supplies the tag with power. Passive tags contain a coiled antenna within them. When radio waves from the reader are incident on passive RFID tag, the coiled antenna forms a magnetic field. The power

produced in the antenna is drawn by the tag and the circuitry is energized by it [15]. Then the tag performs its task of sending the information. Its major advantages include cheaper manufacturing, no need of battery and smaller size. Apart from that its major drawback is its short range, incapability to include sensors due to less power and security issues.

3. BUSINESS AND COMMERCIAL PROSPECTS

The current research in RFID technology has already shown that it has a vast commercial scope. At present RFID is an emerging technology. Its power has been realized but its capabilities are yet to be utilized completely. As this technology gets developed, its use will eventually increase. RFID has a large business scope. In business, reader reads the tag then sends the information, identification and location of the object to a computer. Now with this information further business processes are initiated [20]. There has been an outbreak in many areas of research with RFID such as environment management [27], project management [28], e-commerce [29], information systems [30] [31], innovation management [32], supply chain management and warehousing [33] [34]. With the help of a well organized inventory system RFID systems can help in preventing theft, shop lifting, error and fraud losses, which amounts to nearly $31 billion USD in US [36]. The retail industry has been completely changed and it is strongly believed that "Retailing in the 21st century will no doubt be very different from retailing in the 20th century, just as retailing in the 20th century was very different from retailing in the 19th century" [35]. The distribution of RFID tags in different industries is shown in Fig.7., which clearly depicts the largest share in retail industry [8].

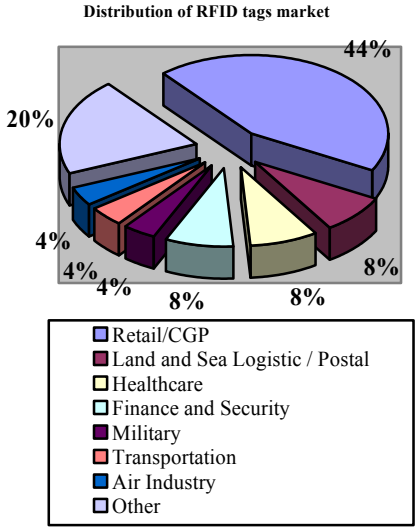


Fig.7. Distribution RFID tags market

The main RFID device in use is EPC (Electronic Product Code). The development of standards for these devices is overseen by EPCglobal Inc. which is a joint venture of EAN and UCC, the bodies which controls the regulation of Barcodes in US and rest of the world [42]. In large quantities, EPC tags may even cost cheaper than 13 US cents [43] and is expected to drop to as low as 5 US cents in a few years [44]. Many big companies are in RFID manufacturing and services today such as IBM™ and Infosys™. They are building RFID tags and reader system for commercial market requirements. Some major IT enterprises also provide commercial software for RFID [2], such as IBM™ Websphere and SUN EPC network provided by Sun Microsystems™. Commercial status of RFID is bound to increase in the near future.

A large number of products in America are handled through retail supply chain and majority of them still rely on manual methods of data collection [37]. Wal-mart has been studying and researching the business applications of RFID and has become one of the biggest user in retail market [48]. Wal Mart [24] and US department of Defence [25] ordered their suppliers for implementation and usage of RFID by beginning of 2005 which made the academic community to shift towards it. Many retail industries such as Metro AG, Tesco and 7-Eleven have started using RFID in their supply chain management [49]. This not only helps them optimize their supply chain management but helps them to know exactly where their products are at any time and these products can be tracked down in the chain easily.

India being the second largest growing economy, RFID technology is also getting rapidly adapted in Indian market [38]. RFID is extensively used in apparel industry in India. Many retail industries such as Pantaloon and Madura garments have started using RFID to tag garments for SCM [38]. In Wipro's Electronic City many stores such as Arving Mills sell RFID tagged products. Mahindra and Mahindra is using RFID for integrated production management [39]. Jayakar Library of Pune University and Dhanvantri Library of Jammu University are using RFID for library management purposes. Ashok Leyland is also preparing to deploy RFID in its assembling centers [38]. In order to reduce retail shrinkage many large retail outlets in India such as BIG BAZZAR and PANTALOON are using RFID [39].

3.1 Applicable Fields and Areas

RFID has a wide commercial scope. Some of the current applications are listed below:

3.1.1 Banking

RFID has a large number of applications in banking. It can help in the management and enhancing the security of banking systems. Customers can be given RFID of their accounts along with a pin code with which they can perform transactions, similar to performing transactions from ATM. But these transactions can be made more interactive, sophisticated and these identities can be used at multiple places for more functionalities.

3.1.2 Goods management in stores

RFID can be used on goods for their identification. RFID can replace Barcodes and they may store additional information. With the help of RFID the goods can be monitored and security can be increased. RFID readers can be placed on the exits of stores so that all the goods or objects going out can be monitored [to be cited].

3.1.3 Asset tracking

With the help of smart RFID active tags we can track assets. Hybrid systems can be made in which RFID system is coupled with enterprise and wireless systems to monitor products, gather information and transfer data from mobile repositories inside and outside a particular zone in time intervals accurately [21, 22].

3.1.4 Animal tracking

RFID tags can be used to track animals [7]. Implantable RFID tags have been used for tracking livestock for many years [6].

3.1.5 Security

RFID can also be used for security purpose. The objects which are to be securely monitored are tagged and then reader monitors the tags continuously [1]. In this way when the item is taken out of range then we can alarm the event.

3.1.6 Hospitals

RFID can remarkably benefit hospitals [45]. In hospitals RFID can be used to tag medicines, syrups and drugs which can prevent misshapen in hospitals.

3.1.7 Library

In large libraries books can be tagged for easy management. When issuing a book librarian can just use a reader and it can send an entry to the computer about the books ID.

3.1.8 Goods transport and checking

RFID may also be integrated with accelerometers so that we can detect jerks and drops. This can help in determining lack of care with fragile items, besides eliminating the need for barcode [1].

3.1.9 Military

RFID has been used in military operations from a long time. RFID were initially used for aircraft identification and can be used for other military purposes.

3.1.10 Healthcare

Some specially designed RFID can be even used to monitor heart beats of humans [1]. This can help in alarming the person if his heart beat rate is not under normal functioning limits.

3.1.11 Passports

Passports and other such documents can also be tagged with an RFID. International Civil Aviation Organization has released guide lines for RFID passport and other such documents [46] [47]. Such passports contain a tag which contains all the information of the person including his photo.

3.2 Limitations and Challenges

Besides a lot of research going on in the field of RFID, it has some limitations. There has been a lot of research on the battery with RFID tags. Power supply for the tag is one of the major concerns. Active tags are dependent on battery and thus have a short lifespan and batteries need to be replaced after their depletion, but for some micro devices of small size, as small as 1mm3 it is very difficult or nearly impractical. With the help of MEMS energy scavenger we can harvest vibration energy. A model was proposed by Tolga KAYA et al. in which vibration energy was harnessed for the power needs of the device [1]. But the main question for these types of devices is that, is the power generation sufficient for device and can we add sensor on these tags. Low cost RFID on other hand have very low power at their disposal which also limits their processing power. There is no proper hardware in such RFID's which can handle conventional encryption methods as a result we have a need for an encryption method which requires less resources. But less resources doesn't mean that security can be gambled. P. Israsena [10] proposed the TEA algorithm, which can fulfill low cost RFID requirements. A .21mm2 RFID implementation of TEA with .35micrometer CMOS was estimated to consume 7.37microwatt of power.

Much of research is being done in transponder to increase its range, making it more power efficient and decreasing its size. Lu H.M. et al. [6] proposed a new transponder which is based on MEMS, and it powered inductively. The device is of few millimeters of length and operates at 13.56-27MHz. A low inductance solenoid conductor is used as coupling element. The device can be used at a distance of 10mm.

RFID tag stored identification data can be read rapidly [11]. As the data is vital it can be traced in open radio frequency environments and thus proper security measures are needed. Low cost tags do not provide any type of data access control which can restrict any unauthorized readers from gaining access to the data. One solution to this problem is that the tag will send its data or information to reader only after proper authentication. An authentication protocol was proposed by Hun-Wook Kim et al. [11] in which the tag authenticates the reader and the communication is done using stream encryption. However a lot of processing is involved which still poses a problem. Most of the RFID devices are not capable of doing large computations so encryptions or protocols requiring a lot of processing power won't be able to fit in. Multiple tags may send information at the same time. This can cause collision between different tags and reader. Also we if more than one tag is in range of the reader than there is an ambiguity that which tag will be read. Ismail I. et al. [9] proposed an anti-collision protocol which avoided collision of tags sending data at the same time. He also proposed a positioning method which could get information from a particular tag when more than one tag is in range of the reader.

To nearly block or disturb the operation of a RFID reader we can also use active jamming in which the user sends an active RFID signal continuously [19]. Tags can be deactivated using a "kill command" after which the tag cannot be used anymore and it can't be activated again [bothAbove]. This was proposed by the Auto-ID center in MIT [17, 18]. By using a metal mesh container or a container made of foil impenetrable by RF waves we can protect a tag by shielding it from RF waves, such a container is called Faraday cage [19]. To cope up with many of its limitations, RFID technology is being merged with WSN technology, to increase its features and applicability. When combining RFID with WSN technology energy efficiency is one of the major issues [4].

3.3 Future

RFID is an emerging technology and will improve over time. RFID can bring about some great breakthroughs commercially.

RFID business is facing some challenges today. Until the requirement of RFID grows commercially RFID manufacturing and other middleware software making companies won't expand their RFID business much. There has been some good work in field of RFID to make it more powerful in the commercial market.

A new and more powerful technology would be combining the two, RFID and WSN. RFID integration with wireless sensor network (WSN) can be done in some ways [2], where RFID being used to identify objects while WSN providing context environment information of these objects. Lei Zhang et al. [4] has proposed three ways to merge RFID and WSN. Zigbee protocol was proposed by him, which has low power consumption, less memory usage, high reliability and has a Zig bee IC which is specially designed low power IC. He also proposed the integration of RFID into WSN base station. But the main drawback of Zigbee protocol is that it has a slow data transfer rate and his technique is not suitable for outdoor environment. EPC Sensor Network (ESN) architecture based on the EPC global architecture was proposed by Wexin Wang et al. [2] as an integration system of RFID and WSN. To handle large volume of events from distributed sensor readers and RFID, complex event processing is used in ESN middle ware.Pereira D.P. et al. [7] proposed a new model to integrate RFDI and WSN in which active RFID tags were used for identification and WSN sensor nodes consisted of RFID reader. In this model the sensor nodes consisted of three parts, a sensing part which senses the environment temperature and other things, a reader which communicates with RFID tags and a transmitter which transmits the data back to station.

A lot of work is going on to bring RFID successfully in the commercial market. In future we expect to see small transponders which can work at large range. These transponders will be passive, i.e. they will generate power from the incoming signal, from environment or from any other free source. These transducers will be integrated with other sensors such as temperature or humidity sensors. Such large range and highly efficient transducers will bring a breakthrough in RFID technology.

4. PROPOSAL

RFID technology can be integrated into mobile phones. RFID readers can be integrated in mobile phones which can bring a major breakthrough in pervasive computing. If RFID readers can be successfully integrated into mobile phones then it can be used for many purposes. In today's world mobile phones are a common thing. Currently India has the largest number of mobile phone users. If mobile phones are scattered throughout the country so densely then this can be taken to an advantage. If every mobile phone can be used as an RFID reader then their can be unimaginable possibilities of what can be done using it. Tagged objects, animals and even persons can be tracked using it. If this technology is supported by the mobile network service provider then the mobile's RFID reader can be used to send information back through the mobile phones network. This information which has been sent to the service provider can be then utilized for any purpose.

Their have been some attempts to merge RFID and WSN into mobile entities. Also some frameworks were presented for mobile wireless sensor networks and RFID. WISSE [3] is one such framework in which mobile entities build groups by interaction and with shared context information they can easily receive services from Service Layer. WISSE consist of a context layer which handles the interaction amongst mobile entities.

Some devices have been made for adding RFID reader functionality to mobile phones, one of such device is *Syscan* RFID reader module for PDA's CF slot. Simple ASCII protocol was used for communication between the reader module and PDA. Commands were sent using PDA and the results were returned to PDA [16].

People often keep changing their mobile phones. They sell their old phones and purchase new ones which are having new features. If all the mobile manufacturers start integrating RFID readers into their upcoming mobile phones from now then in nearly 5 to 10 years every mobile user will be having a RFID reader integrated mobile phone, so availability won't remain an issue.

4.1 Applications

4.1.1 Banking

Banks can provide their customers with cards integrated with RFID tags. RFID reader integrated mobile phones can be used to read the RFID banking card. This can allow the customer to purchase things wirelessly. The card will be read using RFID reader integrated mobile phones as shown in Fig.8. This ID information will be sent to mobile phone communication service provider, so that it can be used for further transaction or processing. Banks will provide every RFID card with a pin code. The user will be required to enter this code for every transaction using the RFID banking card. This pin code system will prevent people having RFID reader integrated mobile phones to read other people's RFID banking card.

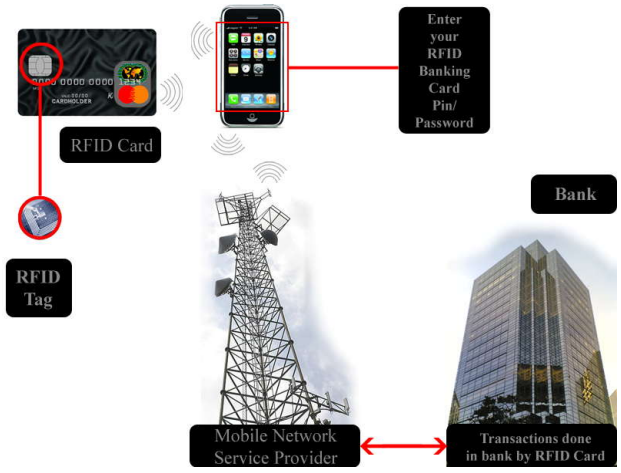


Fig.8. Banking with RFID Cards and RFID mobiles

4.1.2 Person identification

It is believed that in future persons will be integrated with an RFID chip inside them which will be used to identify the person ,as shown in Fig.9.. This chip will store his identity which will be used for every transaction he performs such as purchasing, banking transactions etc. and other places where he needs to authenticate his identity. If such chips are integrated in persons than mobile phones can be used to track persons, as shown in Fig.10.. Every mobile phone can send the ID information of persons around that mobile phone. This information can be sent to the mobile service provider from where it can be used for further purpose. The position of the mobile phone is known to the service provider and in this way we can get the position of the RFID tag which is being detected by the RFID reader integrated mobile phone. In this way we can have a virtual world which can be used to track people or objects. Such type of system would need high security. In such system the information on the tags would have to be stored in encrypted form.

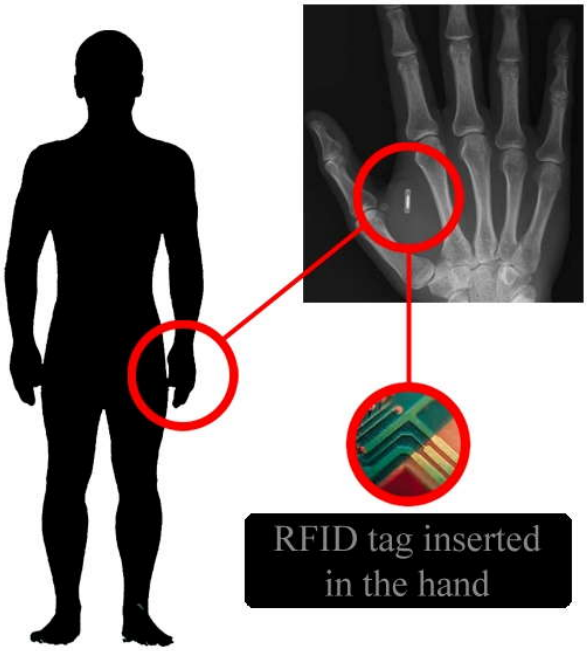


Fig.9. RFID tag inserted in the hand

Some people having RFID reader might try to read the tags of other people to obtain their private information. If he is able to read the ID of the tag then he may misuse that ID for other purposes. Such type of intrusion can be prevented by a key system. A key will be sent from the service provider and this key will be sent to the tags then only the tag will send its information to the reader. This key system will prevent people having RFID reader mobile phones trying to read the tags of other people. The reader hardware has to be made such that the underlying information doesn't get in the hands of the mobile phone owner. So the communication between the RFID tag and the mobile service provider has to be made secured.

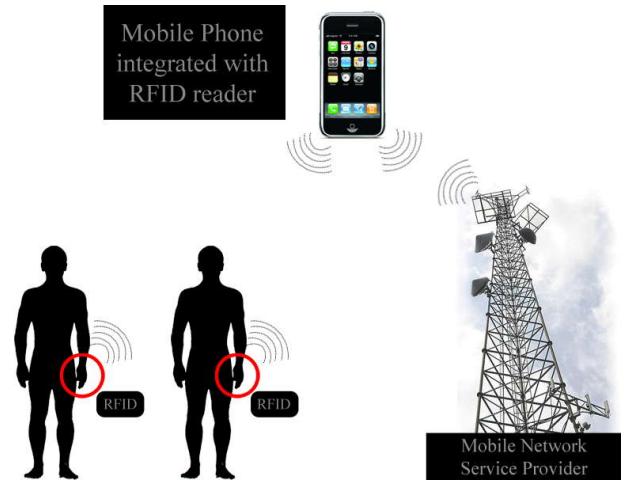


Fig.10. Mobile integrated with RFID reader

4.1.3 Universal ID

Every object can be given a identification code. Using the RFID reader integrated mobile phone one can read the RFID tag on an object and send this ID to the mobile phone communication service provider. The provider can identify the object and can send a description of that object. This information can then be used for further transactions or processing.

5. DISCUSSION

Integration of RFID technology into mobile phones can bring about a revolution. The major challenge in current era is cost of RFID readers. RFID readers are very costly, nearly thousands of US dollars per reader [40]. The cost of integrating such devices would be even greater. As research and development in RFID reader technology progresses, new innovative manufacturing techniques will emerge over time. The size of mobile phones is small and with integration of RFID reader its size would be considerably increased. Battery of mobile phones also remains a big issue. RFID readers will consume the battery of mobile phones quickly. Low consumption and highly efficient RFID reader devices will be needed if they are to run on a mobile battery backup, and that too with the battery shared with mobile. In future when Nanotechnology becomes more mature, nano-batteries would be used which would be smaller and more efficient.

Previously we have worked in reliability analysis of Nanotechnology and MEMS devices. We are currently working on design and implementation of integration of RFID reader into mobile phones. Our software team is working on the middleware software and protocol design for such a system. We are also working on some designs which would use MEMS and Nanotechnology to make these devices smaller and more power efficient. Even if nano-batteries can be successfully integrated in such a design, their cost would be a major issue.

6. ACKNOWLEDGMENTS

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