Near Field Communication (NFC)

EE174 – SJSU

Tan Nguyen

This presentation was taken from EE174 @ SJSU as indicated above. It was originally given my Prof. Tan Nguyen, who is a Lecturer in the department there, as well as an engineer at IBM in San Jose, California.

It is being used as the framework for a presentation in 14-760 at CMU in Spring 2019.

OBJECTIVES

- **RFID**
- **NFC**
  - **NFC Operations**
  - **NFC Applications**
  - **NFC Advantages/Disadvantages**
  - **Summary**

What is RFID?

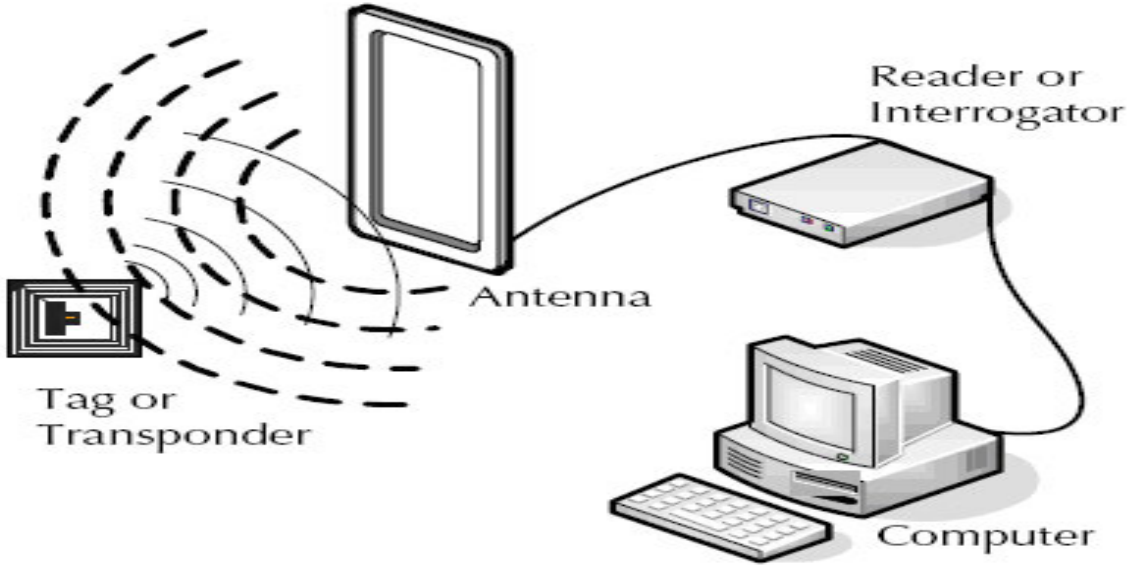
- Radio-Frequency Identification (RFID) is the use of radio waves to read and capture information stored on a tag attached to an object. A tag can be read from up to several feet away and does not need to be within direct line-of-sight of the reader to be tracked.
- The RFID device serves the same purpose as a bar code or a magnetic strip on the back of a credit card or ATM card; it provides a unique identifier for that object. And, just as a bar code or magnetic strip must be scanned to get the information, the RFID device must be scanned to retrieve the identifying information.
- RFID mostly use frequency ranges:
    - LF: 125-134KHz
    - HF: 13.56MHz
    - UHF: 433MHz, and 860-915MHz

How RFID Works

A RFID system consists of:

- A tag or label.
- A reader.
- Ant

RFID tags or labels are embedded with a transmitter and a receiver. The RFID component on the tags have two parts: a microchip that stores and processes information, and an antenna to receive and transmit a signal. The tag contains the specific serial number for one specific object.



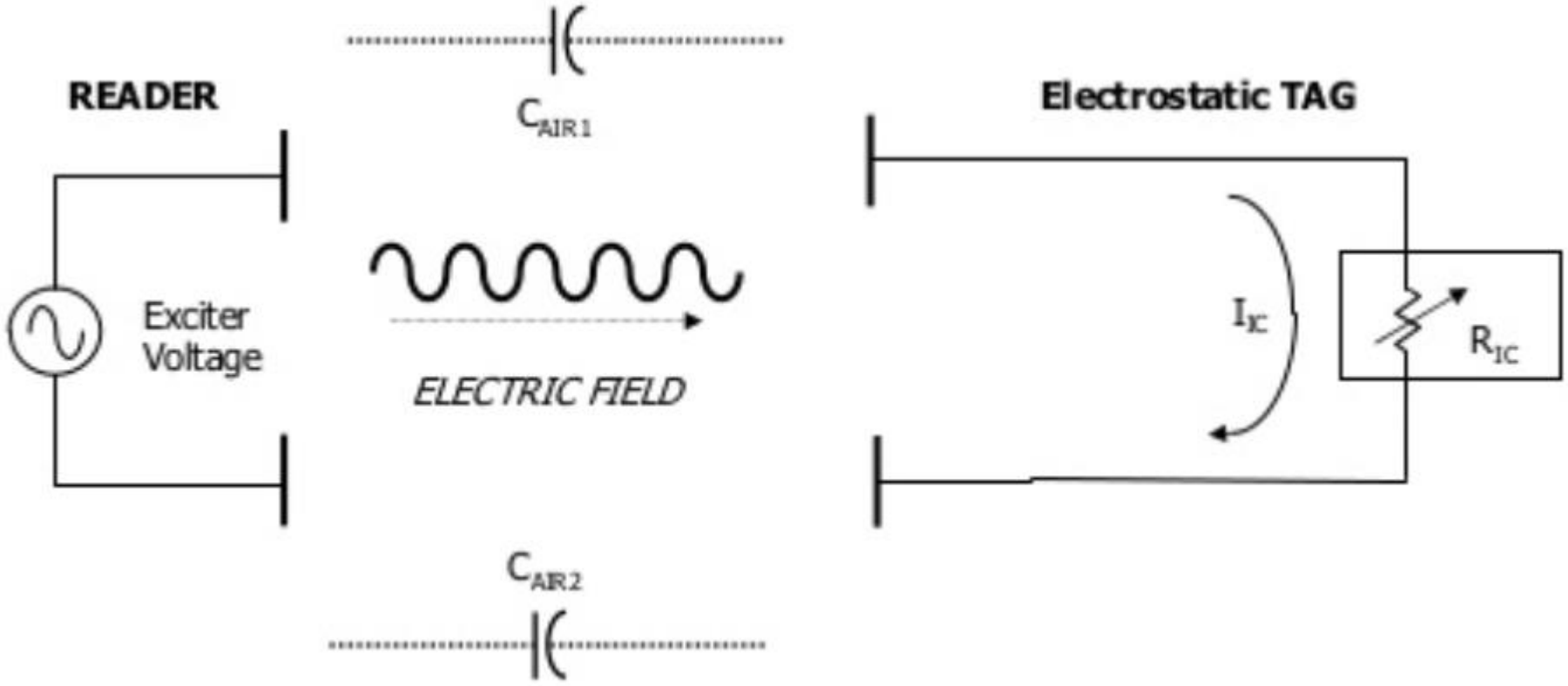
To read the information encoded on a tag, a two-way radio transmitter-receiver (called an interrogator/reader emits a radio-frequency signal in a relatively short range to the tag using an antenna. In case of passive RFID tag, the RF radiation also provides the energy to the passive RFID tag to communicate.

The tag responds with the information written in its memory bank. The interrogator will then transmit the read results to an RFID computer program.

Added Slide: Capacitive Coupling

- Devices are very close
  - Effectively touching
  - Application example: Hotel key cards that slide into lock
- Each device has an electrode
- Two electrodes together form two plates of a capacitor
  - Requires common ground
  - Capacitors block DC components
  - But let AC components pass – Data transmission

Added Slide: Capacitive Coupling

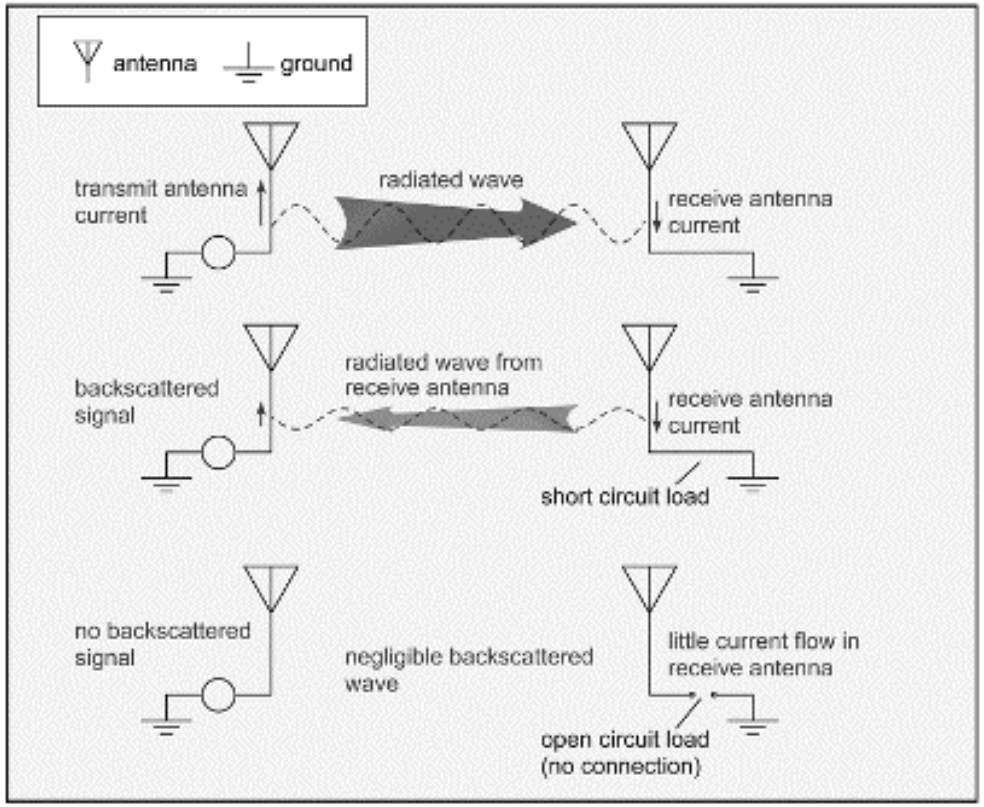


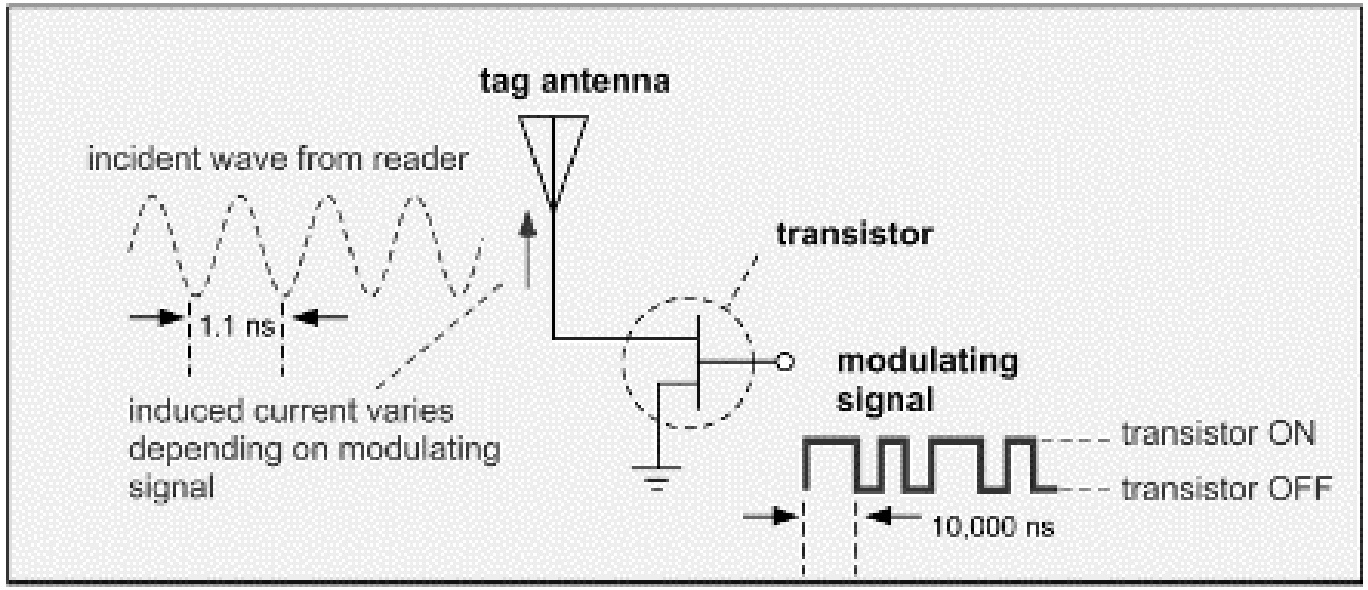
Source: https://www.slideshare.net/TimCollins14/inemi-printed-rfid-presentation/6

Added Slide: Backscatter coupling

- Good for a few meters at most
- Tag reader sends a carrier
- Carrier bounces off of tag
- Energy from carrier is used to drive a simple circuit
  - This circuit alters the properties of the tag's antenna
  - The altered properties of the antenna change the way the signal bounces back
  - This might be accomplished by using a semiconductor to switch a resistance in and out of the antenna circuit
- Tag reader filters out its own signal from the one bouncing back
  - "directional coupling"
  - Differences in modulation are read as data

Added Slide: Backscatter coupling





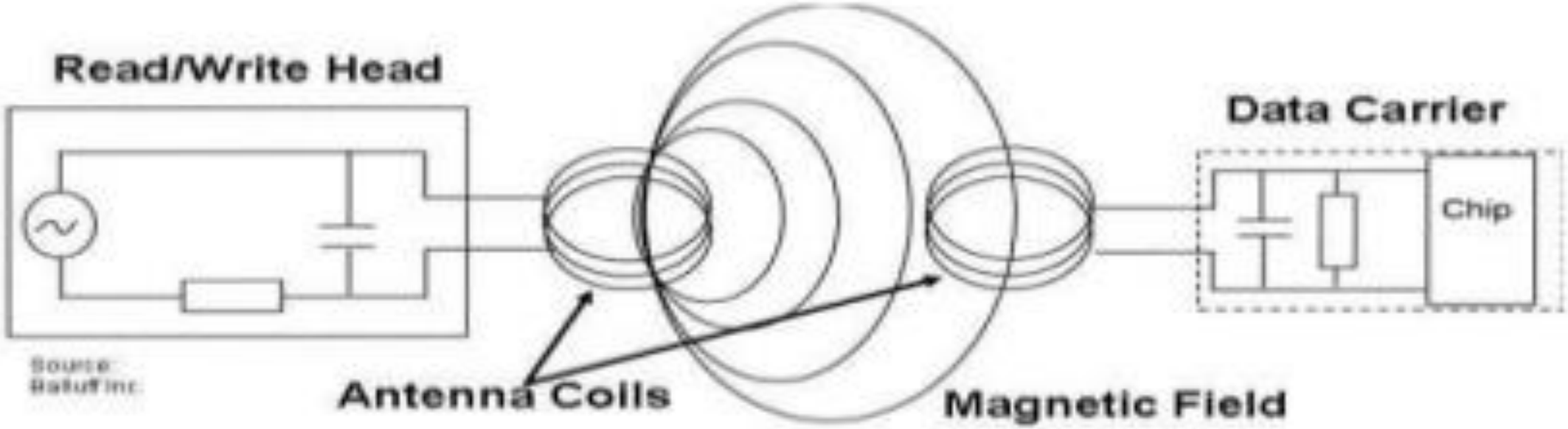
https://www.eetimes.com/document.asp?doc_id=1276306#

http://books.elsevier.com/us/newnes/us/subindex.asp?isbn=9780750682091

Added Slide: Inductive Coupling

- Good for a few to several centimeters
- Each device has a ring antenna
- When close enough ring antennas allow for inductive coupling
  - Thing back to high school physics
  - Changing current flow means changing magnetic field
  - That changing magnetic field (“flux”) in turn induces a changing current flow and “induced voltage”
  - Basically like a transformer with a core made of air.
- Reader sends energy to power tag
- Varying load on tag is detected by reader
  - This is how the communications from tag to reader works.

Added Slide: Inductive Coupling



From slide 9

Passive RFID Tag

There are two types of RFID tags:

- Passive or non-battery powered RFID tag
- Active or battery powered RFID tag

A **passive RFID tag** that does not contain a battery will use the interrogator's radio wave energy to relay its stored information back to the interrogator.

- **Disadvantages of a passive RFID tag**:
  - Can be read only at very short distances, typically a few feet at most. This greatly limits many applications.
  - It may not be possible to include sensors that can use electricity for power.
- **Advantages of a passive RFID tag**:
  - Functions without a battery and have a useful life of twenty years +.
  - Less expensive to manufacture
  - Much smaller (size of a grain of rice). These tags have almost unlimited applications in consumer goods and other areas.

An **active RFID tag** is equipped with a battery that can be used as a partial or complete source of power for the tag's circuitry and antenna. Some active tags contain replaceable batteries for years of use; others are sealed units.

- **Disadvantages of an active RFID tag**:
  - Cannot function without battery power, which limits the lifetime of the tag.
  - Typically more expensive.
  - Is physically larger, which may limit applications.
  - Higher cost for maintenance if the batteries are replaced.
  - Battery outages can result in expensive misreads.
- **Advantages of an active RFID tag**:
  - Can be read at distances of one hundred feet or more, greatly improving the utility of the device.
  - May have other sensors that can use electricity for power.

http://blog.atlasrfidstore.com/what-is-rfid-used-for-in-applications

1. Logistics & Supply Chain Visibility

Photo courtesy of Walmart.

2. Item level inventory tracking

3. Race timing

4. Attendee Tracking

5. Materials management

6. Access Control

7. IT Asset Tracking

8. Tool Tracking

9. Kiosks

Photo courtesy of The Campus Crop.

10. Library Systems

11. Laundry Management

12. Interactive Marketing

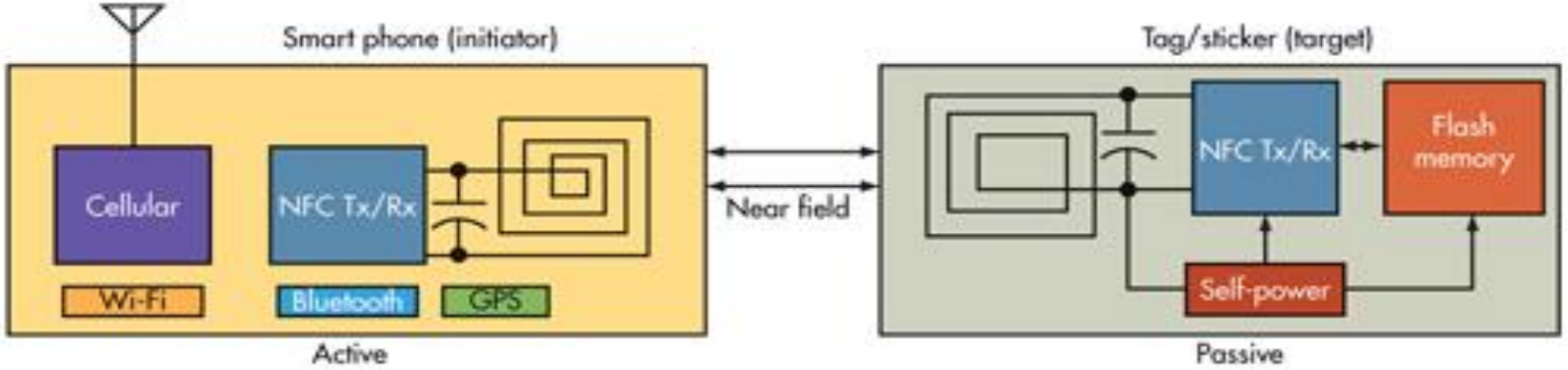
What is NFC?

- NFC is an offshoot of RFID with the exception that NFC is designed for use by devices within close proximity to each other.
- NFC is a short range high frequency wireless technology that carry secure two-way interactions between electronic devices.
- NFC utilizes electromagnetic radio fields while technologies such as Bluetooth and Wi-Fi focus on radio transmissions instead.
- NFC provides contact or contactless communication in a proximity of 1 – 4 centimeters and up to 10 centimeters.
- NFC is mainly aimed for mobile or handheld devices.
- NFC allows communication between:
  - Two powered (active) devices
  - Powered and non self-powered (passive) devices.
- NFC offers the ultimate in security and convenience, and makes new interactions possible.
- NFC combines the interface of a smartcard and a reader into a single device that allows two-way communication between endpoints, where RFID system was one-way only.
- NFC devices operate at 13.56MHz, with a bandwidth 14kHz.
- NFC supports data rates: 106, 212 and 424 Kbits/s
- For two devices to communicate using NFC, one device must have an NFC reader/writer and one must have an NFC Tag.

NFC Time Line

Year	Event
1983	The first patent to be associated with RFID was granted to Charles Walton
2002	NXP Semiconductors and Sony co-invent NFC
2004	Nokia, Phillips and Sony established the NFC forum
2006	Initial specifications for NFC Forum Tags and “Smart Poster” records
2006	Nokia launches the first NFC phone (Nokia 6131)
2009	NFC Forum releases Peer-to-Peer standards
2010	Samsung, Nexus 5: First Android NFC phone shown
2010	AT&T, Verizon, T-Mobile announces Softcard mobile payment joint venture
2011	Google I/O “How to NFC” demonstrates NFC to initiates a game and to share a contact, URL, app, video, …
2011	RIM is 1st company for its devices is certified by Mastercard worldwide, the functionality of PayPass
2012	Samsung introduces TecTile, a set of NFC stickers and a companion App for Android to read/write TecTile
2012	Sony introduces “Smart Tags” using NFC technology to chab=nge modes and profiles on Sony smart phone
2012	Wired US is the 1st mass market publication to feature NFC enable advertisements
2013	Samsung and Vise announces major partnership to develop mobile payments
2014	Apple introduces iPhone 6 with Apple Pay using NFC Tecnology

Active and Passive NFC Devices



Active NFC device usually a microcontroller based like a NFC enabled smartphone, would not only be able to collect information from NFC tags, but it would also be able to exchange information with other compatible phones or devices and could even alter the information on the NFC tag if authorized to make such changes.

NFC reader continuously emits RF carrier signals and keeps observing the received RF signals for data.

A passive device, such as an NFC tag, contains information that other devices can read but does not read any information itself. NFC tag does not have its own power source. It absorbs energy emitted by the reader(phone) and starts sending modulated information when sufficient energy is acquired from the RF field generated by the reader. Data modulation (0s and 1s) is accomplished by either direct modulation or FSK or Phase modulation.

- **Operation:** Active device generates the RF field and the passive device uses the field to power itself and communicate.

Operation Of NFC

1. NFC has two communicative terminals :The **INITIATOR** is the one who wishes to communicate and starts the communication. The **TARGET** receives the initiator's communication request and sends back a reply

2. NFC employs two different coding to transfer data. If an active device transfers data at 106 Kbit/s, **a Modified Miller** coding with 100% modulation is used. In all other cases **Manchester coding** is used with a modulation ratio of 10%.

10% ASK modulation means ASK modulation in which modulation index will range between 8% and 14%.

In 100% ASK modulation, unmodulated signal amplitude and modulated signal amplitude is almost equal.

Operation Of NFC

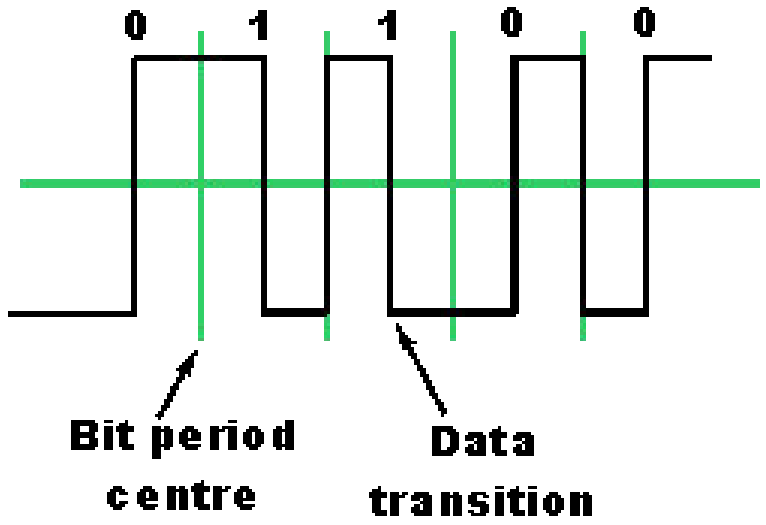
There are two mode of communication

Passive Communication Mode: The Initiator device provides a carrier field and the target device answers by modulating existing field. In this mode, the Target device may draw its operating power from the Initiator-provided electromagnetic field.

Active Communication Mode: Both Initiator and Target device communicate by alternately generating their own field. A device deactivates its RF field while it is waiting for data. In this mode, both devices typically need to have a power supply.

NFC and Manchester coding

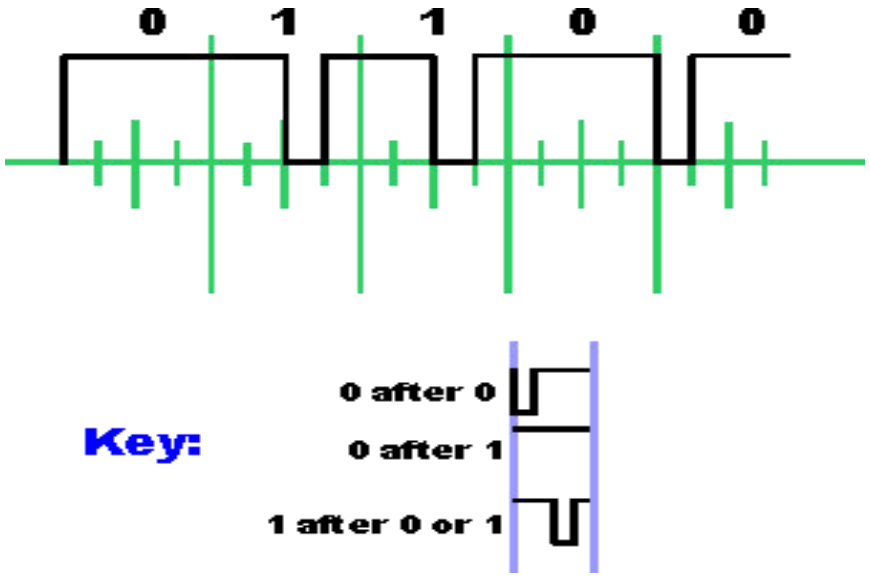
Manchester coding is used for the majority of cases for the NFC communications. The Manchester coding utilises the two different transitions that may occur at the midpoint of a period. A low-to-high transition expresses a 0 bit, whereas a high-to-low transition stands for a 1 bit.



Manchester coding used for NFC data transfer

NFC and Modified Miller coding

Depending on the information to be transmitted, bits are coded as shown below. A high or "1" is always encoded in the same way, but a low or “0" is encoded differently dependent upon what preceded it.



Modified Miller coding used for NFC data transfer used for 106 kbps active device transfers

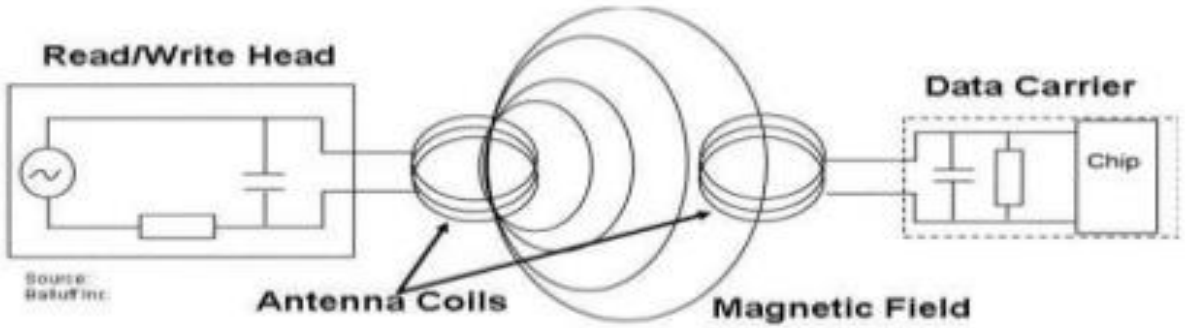
NFC RF signal coding

NFC employs two different coding systems on the RF signal to transfer data. In most cases a level of 10% modulation is used, with a Manchester coding format. However for an active device transmitting data at 106 kbps, a modified Miller coding scheme is used with 100% modulation. In all other cases Manchester coding is used with a modulation ratio of 10%.

DATA RATE KBPS	ACTIVE DEVICE	PASSIVE DEVICE
106	Modified Miller, 100%, ASK	Manchester, 10%, ASK
212	Manchester, 10%, ASK	Manchester, 10%, ASK
424	Manchester, 10%, ASK	Manchester, 10%, ASK

Operation Of NFC

- NFC devices communicate via **magnetic field induction**, where two loop antennas are located within each other's **near field**, effectively forming an **air-core transformer**.
- The reader continuously generates an RF carrier sine wave (at **13.56 MHz**), watching always for modulation to occur. Detected modulation of the field would indicate the presence of a tag.



Operation Of NFC

- A tag enters the RF field generated by the reader. Once the tag has received sufficient energy to operate correctly, it divides down the carrier and begins clocking its data to an output transistor, which is normally connected across the coil inputs.
- The tag's output transistor shunts the coil, sequentially corresponding to the data which is being clocked out of the memory array.
- Shunting the coil causes a momentary fluctuation (dampening) of the carrier wave, which is seen as a slight change in amplitude of the carrier.
- The reader peak-detects the amplitude modulated data and processes the resulting bit stream according to the encoding and data modulation methods used.

Comparison With Existing Technologies

	NFC	RFID	IrDa	Bluetooth
Set –up time	<0.1ms	<0.1ms	~O.5s	~6 sec
Range	Up to 10cm	Up to 3m	Up to 5m	Up to 30m
Usability	Human centric Easy, intuitive, fast	Item centric Easy	Data centric Easy	Data centric Medium
Selectivity	High, given, security	Partly given	Line of sight	Who are you?
Use cases	Pay, get access, share, initiate service, easy set up	Item tracking	Control & exchange data	Network for data exchange, headset
Consumer experience	Touch, wave, simply connect	Get information	Easy	Configuration needed

Operating Modes of NFC devices

Reader/writer mode

the NFC device is capable of reading NFC Forum-mandated tag types, such as a tag embedded in an NFC smart poster

Peer-to-Peer mode

Two NFC devices can exchange data. For example, you can share Bluetooth or Wi-Fi link set-up parameters or you can exchange data such as virtual business cards or digital photos.

Card Emulation mode

The NFC device appears to an external reader much the same as a traditional contactless smart card. This enables contactless payments and ticketing by NFC devices without changing the existing infrastructure.

NFC – How Does It Work?
3 communication modes

Connect the world of apps with the physical world:
Apps jump into the world and touch people, objects and other apps.

Tag/Card Reader/Writer (Terminal)
Multi-standard (ISO/IEC14443, JIS X 6319-4/Felica, ISO/IEC15693)

Connect devices through physical proximity:
A magical connection of devices by simply touching them. A true device "hand shake".

P2P Communication (Device to Device)
NFCIP-1, NFCIP-2 (ISO/IEC18092, ISO/IEC21481)

Interactive wallet:
Allows your phone to act like an "interactive card" for payment, transportation, ID and physical access

Card Emulation
EMVCo/ISO/IEC14443, JIS X 6319-4/Felica

TAP INTO NFC FORUM

Specifications

The NFC Forum has issued various specifications to date:

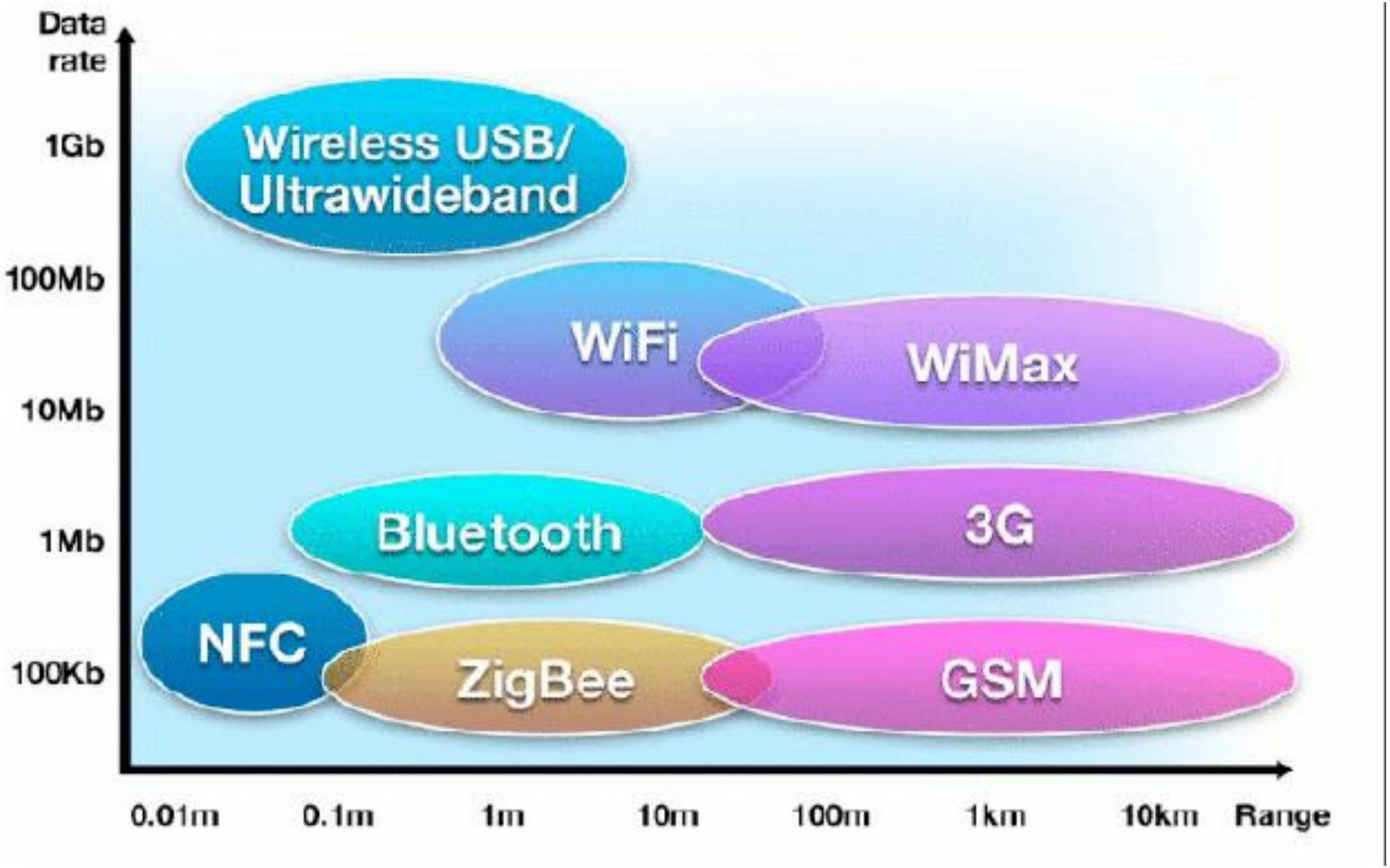
Specification	Purpose
NFC Data Exchange Format (NDEF)	Defines a common data format between NFC-compliant devices and tags
Record Type Definition (RTD)	Specifies rules for building standard record types Five specific RTDs (**Text, URI, Smart Poster, Generic Control, and Signature**) are used to build standard record types
Logical Link Control Protocol (LLCP)	Defines a protocol to support peer-to-peer communication between two NFC-enabled devices
Connection Handover	Defines how to establish a connection using other wireless communication technologies
Operations Specifications for Four Tag Types (1/2/3/4)	Enable core interoperability between tags and NFC devices

BEFORE & AFTER

PREVIOUSLY USED METHODS

CURRENT & FUTURE METHODS

DATA RATE & RANGE



Application of NFC

Application of NFC

Smart Posters

- An object that has, affixed to or embedded in it, one or more readable NFC tags with NDEF messages stored in them.
- Each tag is read when an NFC device is held close to it
- "N-Mark" shows touch point
- Not only a paper poster on the wall
- Billboard, garment tag, magazine page, even a three-dimensional object

The Smart Poster record defines a URI plus some added metadata about it

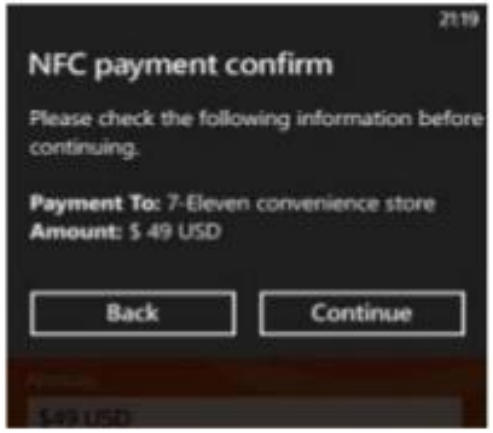
NDEF Message				
Sp (Smart Poster)				application/vcard
URI	Text	Action	Configuration	vCard data

Application of NFC

NFC and Mobile Payment

A customer makes his payment through mobile phone using NFC

- NFC phone will open **wallet** application
  - Wallet will display product cost when user clicks "Buy"
- At check out, wallet will display all credit/debit cards in wallet for payment
- Customer will select card for payment
- Wallet will show the confirmation page with the check out basket
- Wallet will connect to retailer back end for authorization and display tracking information



Application of NFC

Peer-to-peer

- **Connection Handover :** A handover use case is the exchange of configuration information via the NFC link to easily establish a connection over (for e.g. **Bluetooth or Wi-Fi**) and carry the information to be shared. Connection can be set between NFC devices

Speakers (touch to connect)

- *Home computer components*
- *Home entertainment systems*
- *Cameras and printers*
- *In-car devices*
- *Headsets and handsets*
- *Secure WLAN modem set-up*

Smart Tags

- If the amount of information is relatively small (up to one kilobyte), it is possible to use NFC to transmit the data itself (e.g. **electronic business cards, contacts**).

Application of NFC

Additional Use Cases for NFC Smart Posters

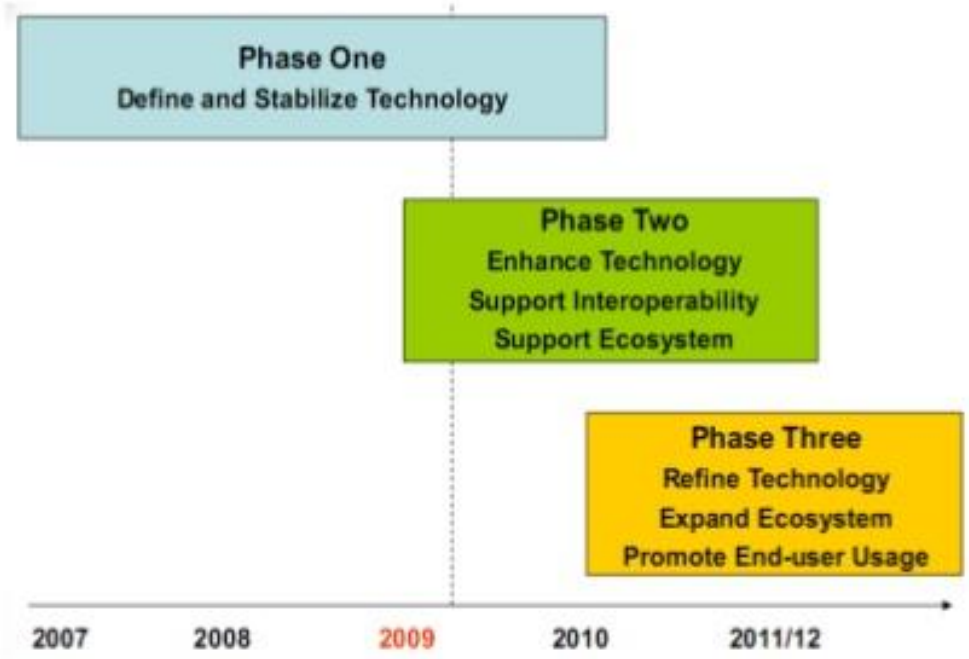
- **Asset Management** - Use NFC phones to read smart tags per product for inventory
- **Access** - Ensure secure building area access for personnel with NFC device and contactless reader
- **Parking** – Use NFC to authenticate parking entry and keep record .
- **Meal orders** – Customers order their meals by touching NFC Smart Posters.
- **Remote worker reporting** – Remote workers confirm locations visited and tasks completed
- **Maps** – An interactive NFC Smart Poster map allows the user to download the map, get additional information on relevant services, and access coupons, etc.
- **Events calendar** – Users can download tickets or coupons or be linked to event websites

<< Security Gate

NFC Parking >>

Evolution and Future of NFC

NFC Projected Development



NFC Forum

The NFC Forum is a non-profit industry association to advance the use of NFC short-range wireless interaction in consumer electronics, mobile devices and PCs.

The NFC Forum promotes implementation and standardization of NFC technology to ensure interoperability between devices and services. In September 2008, there were over 150 members of the NFC Forum.

Benefits of NFC

NFC provides a range of benefits to consumers and businesses, such as:

- **Versatile**: NFC is ideally suited to the broadest range of industries, environments, and uses
- **Open and standards-based**: The underlying layers of NFC technology follow universally implemented ISO, ECMA, and ETSI standards
- **Technology-enabling**: NFC facilitates fast and simple setup of wireless technologies, (such as Bluetooth, Wi-Fi, etc.)
- **Inherently secure**: NFC transmissions are secure due to short range communication
- **Interoperable**: NFC works with existing Contactless card technologies
- **Security-ready**: NFC has built-in capabilities to support secure applications

NFC is as simple as a >> *touch*

Advantages of NFC

1.Convenience: Many consumers will "pay" for convenience because convenience is very important in today's society. NFC is a perfect source of convenience because it merges a mobile device with wallet(s). NFC is also quite intuitive; all it takes is a simple touch when using NFC for payments. Can you imagine how much faster line ups would be at the grocery store, coffee shop, etc?

2. **Versatility:** NFC can be well adapted for all kinds of situations ranging from bank cards to transit passes, movie passes, reward systems and even keys. Ideally, NFC is suited for a broad range of industries and uses because this innovation allows users to manipulate through the development of software.

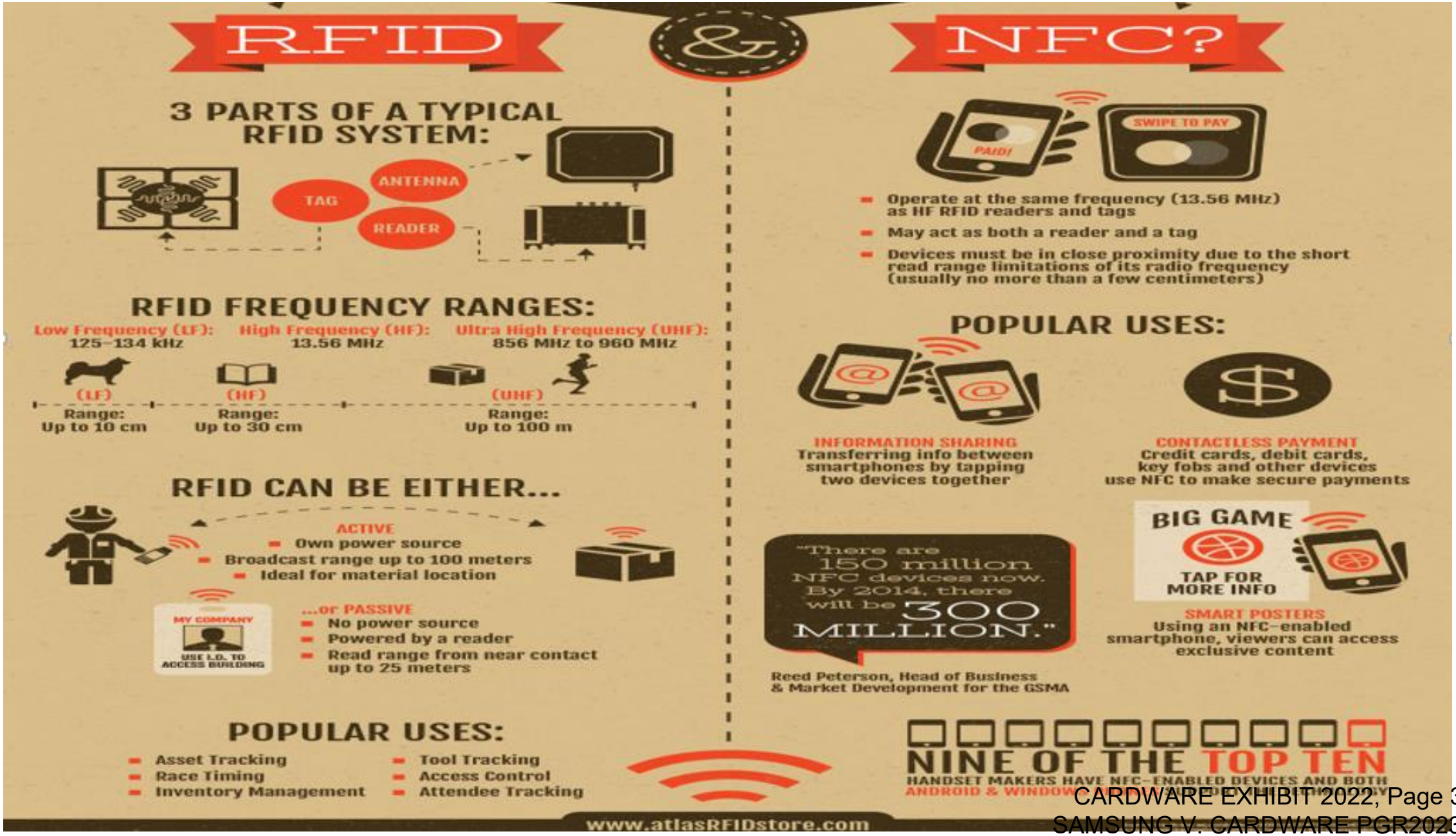
3. **Safety:** Now, you might think how could fusing your wallet into your mobile device be safer. After all, just like a wallet, a cellphone could be stolen. However when your wallet is stolen, the thief has access to all your credit cards and information right away! With smartphones, passwords can be used to further protect your information.

- NFC enabled credit cards are much more secure than a credit card magnetic strip
- Requires PIN
- Retailers no longer have physical access to your credit card information

Disadvantages of NFC

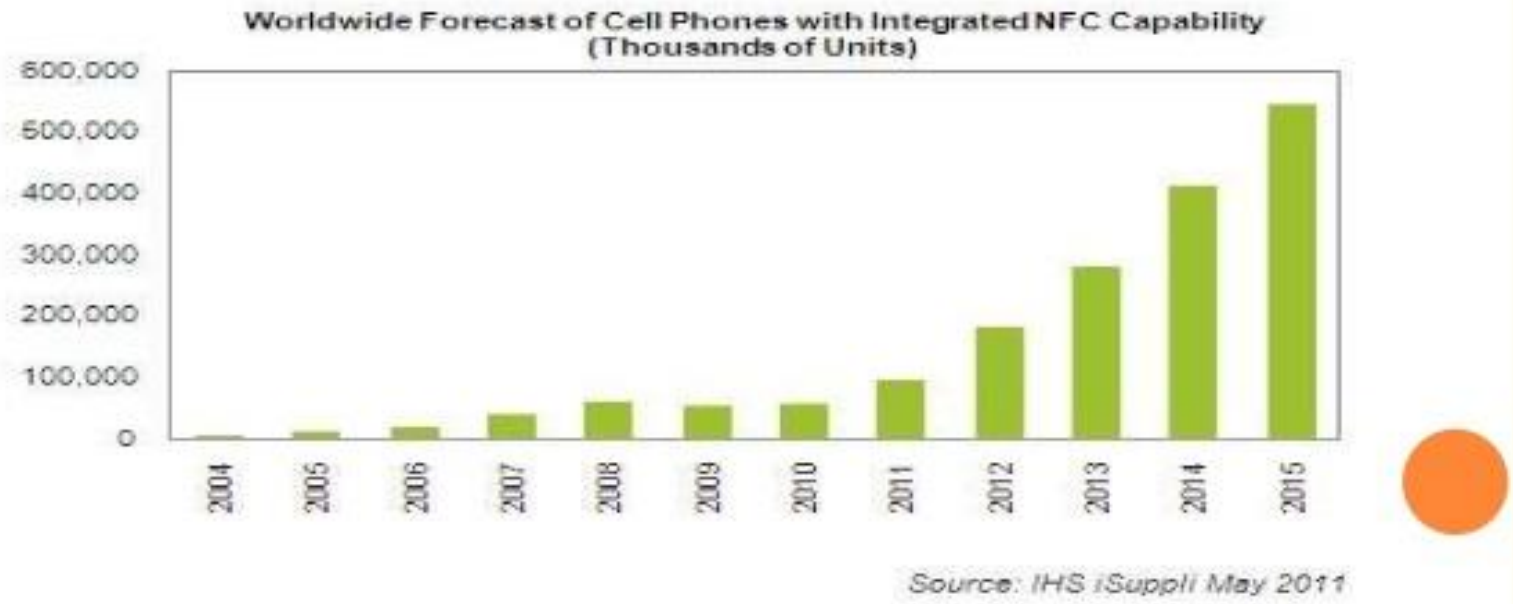
1. Company Agreements to use NFC: Many of us who would like to try out NFC wishes that it can be used everywhere and anywhere. However if companies do not agree to integrate NFC into their business, consumers will not be able to use the technology.
2. Security:
   - Another major risk to NFC is computer hacking or phone hacking. As mobile phones become more developed, they become much like a hand held computer, and as with computers, they become prone to viruses. Hackers will want to gain access to these tiny computers because it contains a lot of important information all in one device.
   - Examples include a phone's owner credit card information, bill payments, social security information, etc. Moreover, as technology advances, it will becomes easier for hackers to do this.
3. Limitations: NFC can be operated under short range (< 10 cm) with data rate is very less at about 106, 212 and 424kbps.

RFID vs. NFC: What's the Difference?



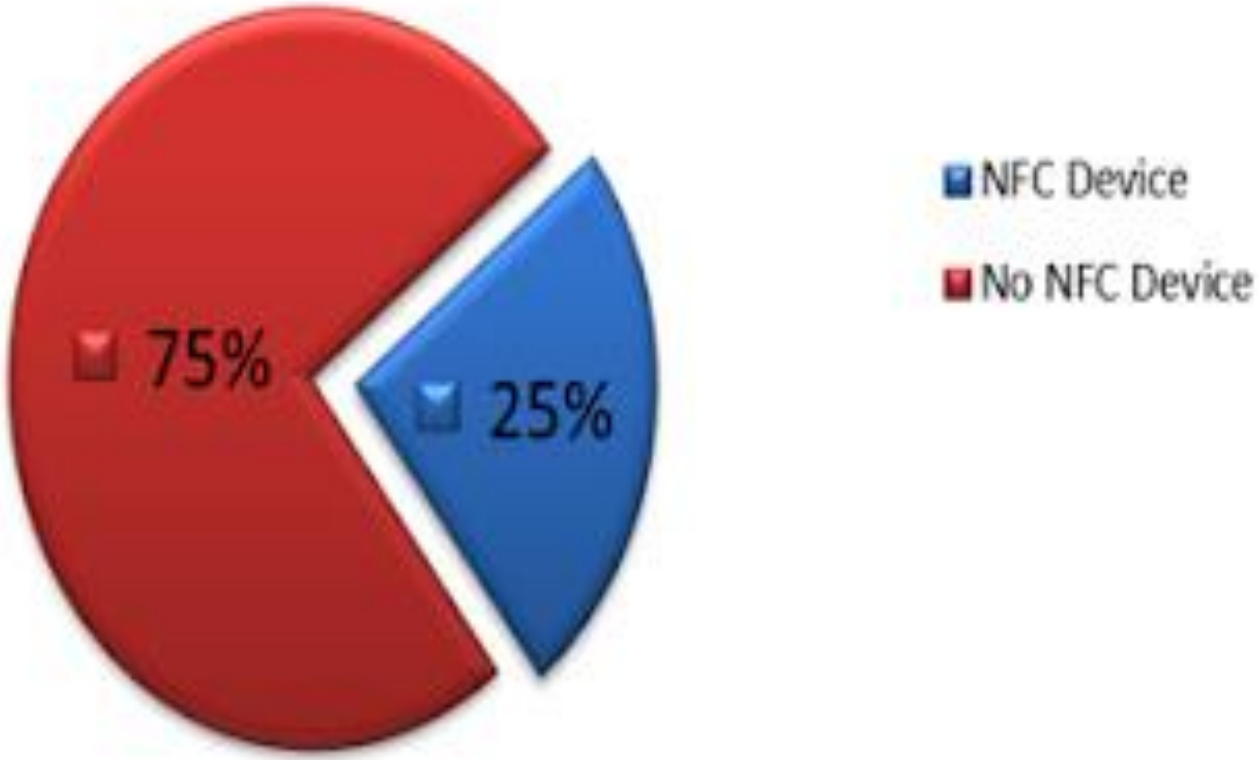
FUTURE OF NFC

- New generations of iPhone, iPod and iPad products would reportedly be equipped with NFC capability which would enable small-scale monetary transactions.
- On May 2, 2011, RIM announced the Blackberry Bold 9900, a new device that will use NFC technology.
- Recently, Microsoft announced that all Windows Phone 8 devices will make use of the NFC technology.



NFC Phones Available Now

Americans with NFC smartphone devices by 2016



Conclusion

- Mobile handsets are primary target for NFC and soon NFC will be implemented in most handheld devices. Even though NFC has the shortest range among radio frequency technologies, but it is revolutionary due to its security, compatibility, user friendly interface, immense applications, etc.
- The advancements in mobile wireless technology and communication standards have enabled usage of contactless and NFC based payment models.
- The mobile wallet based payment model is gaining considerable momentum and is currently being seen as one of the key payment model, to promote contactless payment processing practices.
- The mobile wallet technology enables the end-users to make payments with their mobile wallet accounts, without having to use credit or debit cards and hence this technology can also help users that do not use credit or debit cards.

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