Individual Project Report: Near Field Communication (NFC) Application

Department: 資應所

Student ID: 111065535

Name: 楊文彣

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1. Introduction

Near Field Communication, abbreviated to NFC, is a type of short-range radio technology that allows devices that are held in close proximity to communicate. NFC is rooted in high frequency RFID(radio-frequency identification technology), which operates at 13.56 MHz and allows compatible hardware devices to supply power to and communicate with an unpowered and passive electronic tag through radio waves. The typical communication range for NFC can be up to 10 cm, where there is both a master of the conversation and a slave, just like RFID systems. The NFC standard currently supports different data transferring rates up to 424 Kbit/s.

1-1. History

The technology, NFC, was first developed by Sony, Nokia and Philips. The first device to use an early version of NFC, CommTech, was a Star Wars toy from 1997. Hasbro included a CommTech chip with every single carded 3.75" Star Wars action figure in the 1999 Episode I Collection, and CommTech chips were also included with the three Cinema Scene 3-packs. This resulted in 51 unique CommTech chips (50 chips were packed with figures, and 1 chip came with the Electronic CommTech Reader).

The CommTech technology was applied to give voice to the Star War figures. Each chip reader has an ON button, a button for light saber sounds, a button for blaster fire and four buttons to store all the lines of the figures from a CommTech chip on the device. The quality of the voice samples was hit and miss, in some cases they played back well, and in other cases, the sounds were distorted and it was difficult to make out what was being said.

In 2004, NFC Forum was formed by the companies, Sony, Nokia, and Philips, to promote implementation and standardization of NFC technology to ensure interoperability between devices and services. NFC Innovation Award is held every year to encourage the innovation applying NFC technology.

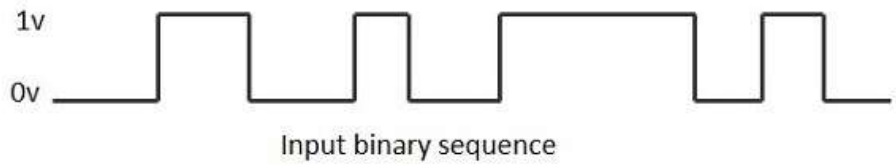
1-2. Features

- Frequency: 13.56 MHz (based on High Frequency RFID)
- Range: 0-10cm
- Specification:
  ISO/IEC 14443 (for smart cards which stores information)
  ISO/IEC 18000-3 (for RFID tags in smart devices)
- Transmission Rate: Up to 424 Kbit/s
- Allow two-way communication
- Apply ASK (amplitude shift keying) modulation for low-speed transmission

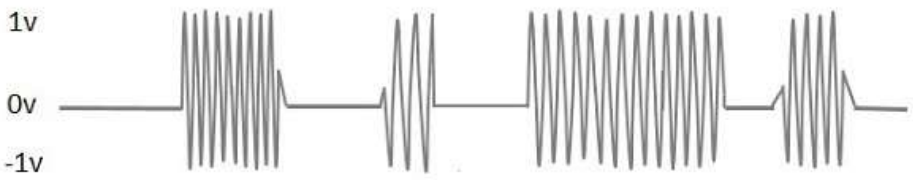
[Amplitude Shift Keying modulation]

Any modulated signal has a high frequency carrier. The binary signal when ASK modulated, gives a zero value for Low input while it gives the carrier output for High input.

The following figure represents ASK modulated waveform along with its input.



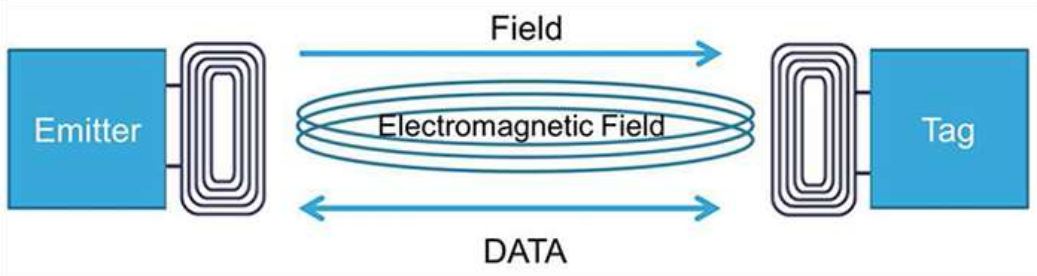
Input binary sequence



ASK Modulated output wave

2. Principle Mechanism

The principle mechanism of NFC communication between two devices is the same as traditional 13.56 MHz RFID, where there is both an emitter, or a smartphone acting like a reader/writer as a master, and the slave is a tag or a card.



The antennas of the emitter and the tag are coupled via an electromagnetic field, and this system can best be viewed as an Air-Core Transformer. An alternating current pass through the primary coil (Emitter) and this current induces a field through the air, inducing current in the secondary coil (Tag). The Tag may use the current from the field to power itself. [5]

Different from RFID, an NFC tag don't need to really be a tag or a card, it can be a modern smartphone. By deactivating its radio frequency field for generating electromagnetic field, a cellphone can act passively like a tag waiting to receive the power from the reader.

2-1. NFC Chip Types

There are three types of NFC chip:

- **NFC Reader Chip**

  The reader chips are the main controller of the communication system. They generate electromagnetic field with antennas and power up with one or more NFC tags to exchanges information.

- **NFC Tag Chip**

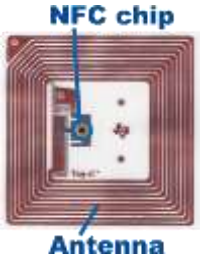
  They are powered by the magnetic field generated by the NFC reader. The NFC tag chips can be classified into two kinds: single-interface NFC chips and dual-interface NFC chips.

- **NFC Controller Chip**

  This kind of chips combine both an NFC reader and an NFC tag for an

integrated solution. They are often embedded in NFC-enabled devices such as smartphones, mobile point of sales (POS), wireless charging devices, etc.

2-2. Two Kinds of NFC Tag Chips



NFC tag is a small memory chip, attached to an antenna. An NFC reader, such as a mobile phone, activates the antenna and the chip with its electric field. This leads to the content being transferred from the chip to the reader, activating the function specified in the tag. The tag chips can be classified into single-interface and dual-interface ones.

- **Single-interface NFC chip**

  The chip is a passive device embedded in an NFC tag. It enables the exchange of data between the tag and the reader once being activated.

  For example, when an NFC-enabled smartphone is brought within reading distance of a wine bottle that embeds an NFC tag in its cork, the NFC reader can verify the origin of the tag and detect if the bottle has been opened, thereby ensuring the product's integrity. [5]

- **Dual-interface NFC chip**

  The tags embed with the chip are called NFC dynamic tags. This kind of chips are coupled with a microcontroller through a wired interface, thereby offering a second communication interface in addition to the NFC wireless link. It enables two-way, wireless communication between two electronic systems, even when no power is supplied to the object carrying the NFC dynamic tag.

  For example, an NFC-enabled smartphone can read the information embedded in the NFC tag of a washing machine, such as the details concerning the condition of the appliance, including fault diagnostics. [5]

2-3. NFC Tag Standard

Based on the tag type, the memory embedded in the tags can be read only, rewritable, or writable once. The data stored on the tags can be URL addresses, Wi-Fi or Bluetooth pairing, SMS, Email, phone configurations, and etc. These data sets are formatted in a structure defined by the NFC Forum. To ensure interoperability among different NFC tag providers and NFC device manufacturers, the NFC Forum has currently defined four tag types. [4]

Tag Type	Use Case	Chip Examples	User Memory (bytes)*	UID Length (bytes)
Forum Type 1	Specialized	Innovision Topaz	90 - 454	4
Forum Type 2	Most common, low cost, single application like smart poster, personal label etc.	NXP MIFARE UL, MIFARE UL-C, NTAG 203, 210, 212, 213, 216 etc.	46 – 142	7
Forum Type 3	Specialized, Asian markets	Sony FeliCa (Lite)	224 – 3984	8
Forum Type 4	High memory applications, high security (in non NFC mode)	NXP MIFARE DESFire EV1 or EV2, Inside Secure VaultIC 151/161, HID Trusted Tag™, NTAG 413 / 424 DNA	1536 - 7678	7
Forum Type 5 (NFC-V / ISO 15693)	Typically industrial rugged tags in various form factors	NXP ICODE SLIx family, EM4233, Fujitsu FRAM MB89R118C, MB89R112, HID Vigo™	32 – 32KB (112 for ICODE SLIx)	8

- **Type 1:**

  These cost-effective tags are ideal for many NFC applications and are based on the ISO-14443A standard, have no data collision protection, 768 bits (96 bytes) of memory expandable to 16kbits (2k bytes) and have a communication speed of 106kbits/s. [4]

- **Type 2:**

  Type 2 tags are similar to Type 1 tags and are based on the ISO- 14443A standard. Like Type 1 tags, they support 768 bits (96 bytes) of memory expandable to 16kbits (2k bytes) and have a communication speed of 106kbits/s. They provide anti-collision support, unlike the Type 1 tags. [4]

- **Type 3:**

  Developed for the Japanese market, these tags use the Japanese Industrial Standard (JIS) X 6319-4, have anti-collision support, and are preconfigured at manufacture to be either read and rewritable, or read-only. The memory can be

variable up to 8Mbits (1M bytes) per service and support communication speeds up to 424kbits/s, but the effective data rate on mobile devices is much lower, typically 106kbits/s. They are derived from the nonsecure parts of FeliCa tags and are typically expensive. [4]

- **Type 4:**

  These tags are also very similar to Type 1 tags. They are based on the ISO-14443A and ISO-14443B standards, support anti-collision, and are preconfigured at manufacture to be either read and rewritable, or read-only. The memory can be variable up to 256kbits (32k bytes) per service and support communication speeds up to 424kbits/s, but the effective data rate on mobile devices is much lower, typically 106kbits/s. [4]

2-4. NFC Modes

- **Reader/Writer Mode**

  The NFC device behaves as a reader for NFC tags. An application on the device can read data from and write data to the detected tag in this mode of operation.

- **Peer-to-Peer Mode**

  This mode enables two NFC devices to exchange information through NFCIP-1 or LLCP.

- **Card Emulation Mode**

  The NFC devices operating under this mode can function as a contactless smart card. Mobile devices can even store multiple contactless smart card.

3. Applications

3-1. NFC In Vehicles

The controller NFC chip in mobile phones can make your smart phone a car key. Through card emulation mode, the smartphone can function as a contactless car key activated by the Car Connectivity Consortium (CCC) Digital Key Reader in the car door. The NFC Forum published the Certification Release 13 (NFC Forum CR13), which enforces version 3.0 of its Device Requirements. This certification will ensure that carmakers offer interoperable key systems using NFC.

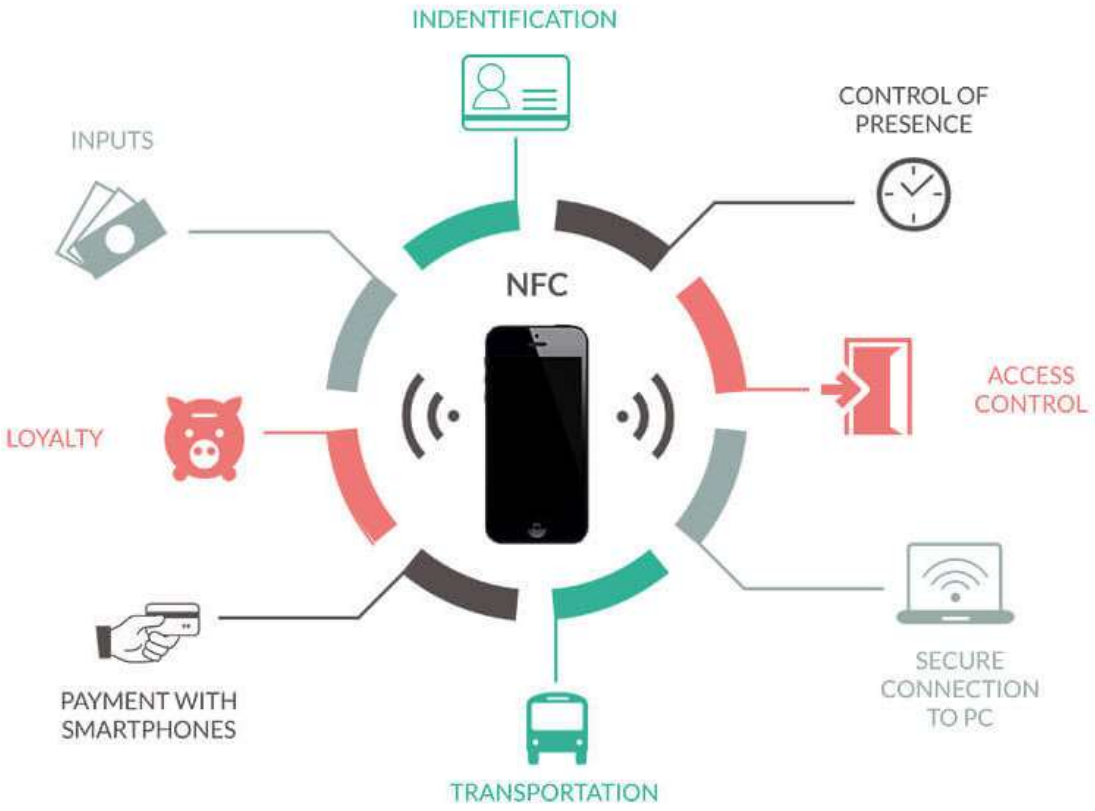
3-2. Apple Wallet

Apple Pay use SE (Secure Element, a tamper-resistant platform, which is typically a one chip secure microcontroller, capable of securely hosting application and their confidential and cryptographic data in accordance with the rules and security requirements set forth by a set of well-identified trusted authorities) to store secret information associated with tokenized cards.

When we try to store our card information in apple wallet, Apple sends the received card information to the relevant card network to validate the card information with the issuing bank. After validation, the card network acting as a Token Service Provider creates a token and a token key, which makes the data be tokenized to replace the Primary Account Number with a token. Afterward, the information is sent back to Apple servers. After the device receives this information from Apple servers, it is saved in the device's SE.

3-3. Transit and ticketing

Contactless tickets will result in increase in speed and ease with which all consumers can use public transport like buses and access-controlled environments like parking lot, transportation gates or get into events, and etc. Not only making travelling comfortable and fast, it also decreases wastage of resources such as paper and time, making it an eco-friendly option along with providing better monitoring thus giving way for transparency of the system.



4. System Architecture

The following is a step-by-step teardown of a Square Reader. [11]

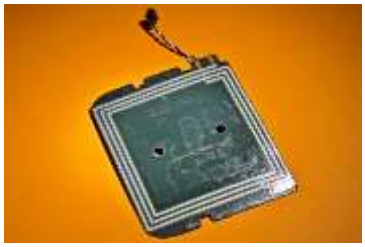
Square Reader is a contactless and chip reader accepts NFC- and EMV-based payments made by Square, a payment processing company. After removing the security lid, we can see circuit board assembly.

It is a two-sided PCB populated entirely with surface-mount components. There is a 3.7V rechargeable lithium battery attached in the back of the PCB. In addition, there are two primary coin cell batteries, size 364.

To control the chip reader, there is a Freescale K21 microcontroller. This is an ARM Cortex-M4-based MCU in a BGA package. This microcontroller has a built-in USB transceiver and a handful of other interface options.

In addition to the Freescale microcontroller, there is also a custom IC that is marked with the square logo. This IC handles the communication with the payment method, while the microcontroller handles the USB/Bluetooth interface.

It's also worth noting that the Bluetooth radio IC used in this device also has a programmable Cortex-M3 core and a Cortex-M0+ in its RF core. That is a total of three ARM cores in this one device.

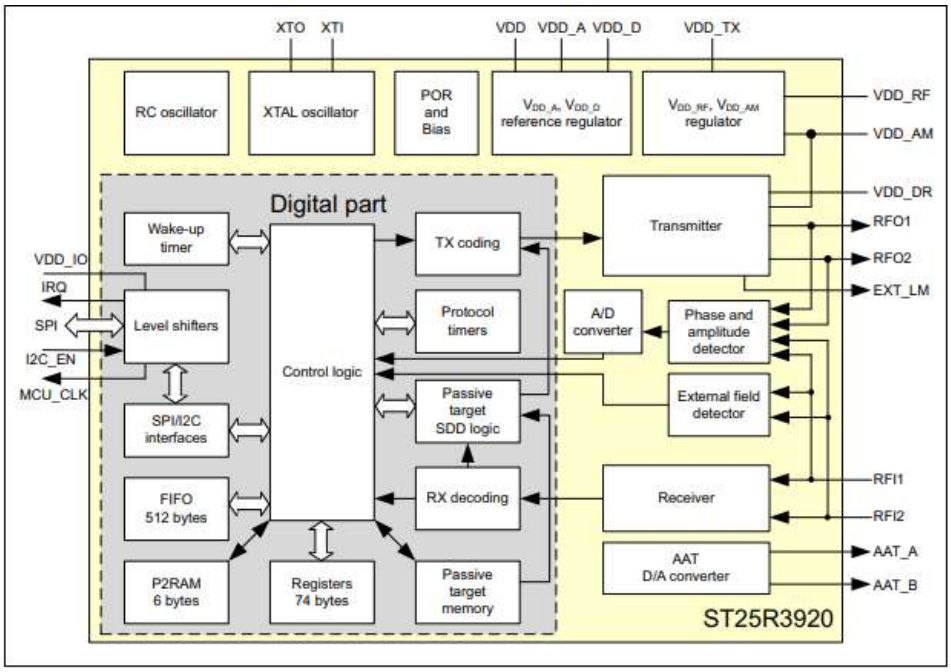


To read the information off of the cards (or NFC devices), this device relies on two methods. The first is an NFC antenna located on the top of the plastic housing. This antenna connects to the PCB via a three-position connector

There is also a ‘chip’ reader for chip-based cards. This mechanism is mounted to the PCB via surface-mount pins and some glue. This slot has tape on the top of it to prevent debris from entering the reader. This slot also has a built-in switch to detect the presence of a card.

5. SoC Architecture

Take ST25R3920, an automotive high performance NFC reader for CCC digital key and car center console from STMicroelectronics for example.



The device includes an advanced analog front end (AFE) and a highly integrated data framing system for ISO18092 passive and active initiator, ISO 18092 passive and active target, NFC-A/B (ISO14443A/B) reader including higher bit rates, NFC-F (FeliCa™) reader, NFC-V (ISO15693) reader up to 53 kbps, and NFC-A / NFC-F card emulation.

The ST25R3920 features high RF power with dynamic power output to directly drive antennas at high efficiency, achieving large interaction distance even with small antenna sizes common in door handles. The device includes additional features, making it incomparable for low power applications. It offers low power card detection by performing a measurement of the amplitude or phase of the antenna signal while reducing power consumption to a minimum. Additionally, it contains a low power capacitive sensor to detect the presence of a card without switching on the reader field.

The ST25R3920 is designed to operate from a wide power supply range (2.6 to 5.5 V from -40 °C to +105 °C, 2.4 to 5.5 V from -20 °C to +105 °C), and a wide peripheral IO voltage range (from 1.65 to 5.5 V).

Due to this combination of high RF output power, low power modes, wide supply range and AEC-Q100 grade 2 qualification, the device is perfectly suited for automotive applications.

6. Market Analysis

6.1. Competitor Analysis

Specification	NFC	RFID	Bluetooth
Maximum Coverage Range	10cm	3meter	100meter
Frequency of operation	13.56MHz	varies	2.4GHz
Communication	2-way	1-way	2-way
Data rate	106,212,424Kbps	varies	22Mbps
Applications	credit card related payments, e-ticket booking	EZ-Pass, tracking items	communication between phone and peripherals

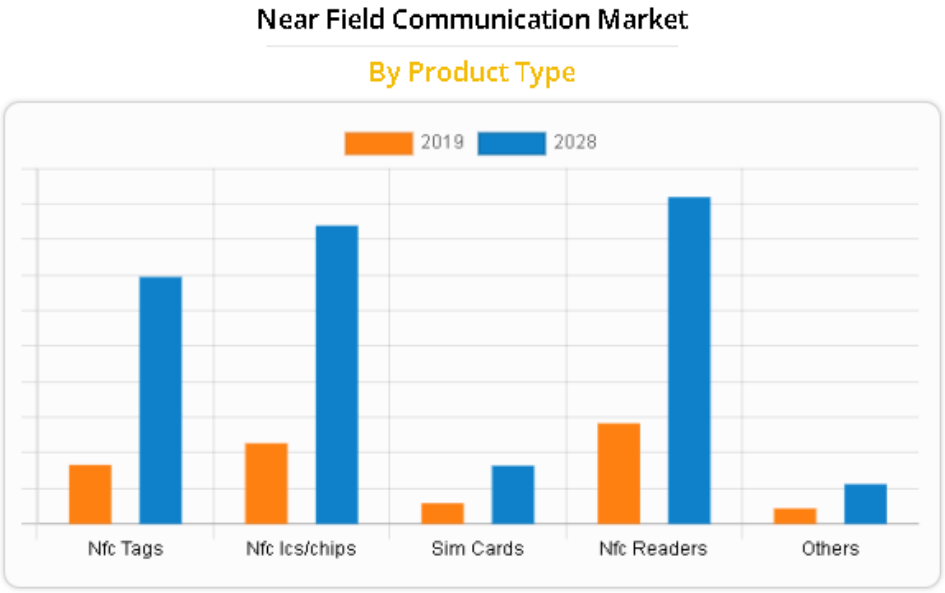
Since NFC and its competitor have their own advantages in different aspect, discussion about the scenarios might be more suitable when comparing these technologies rather than discussing which one is the best.

6.2. Market Forecast

The COVID-19 pandemic has significantly pushed the growth rate of the NFC market owing to the rise in demand for contactless solutions. In addition, factors such as growing use of NFC technology in smart packaging for healthcare and surge in demand for NFC in emerging medical applications due to the pandemic has created lucrative growth opportunities for the market.

Smart wearables and IoT devices are becoming increasingly popular nowadays. With NFC capabilities, the devices allow payment at a store, accessing mass transport system or office building. The need for convenient transfer and the proliferation of smartphones are the factors anticipated to boost the NFC market growth, and the rapid expansion of mobile commerce has achieved unprecedented growth during the last decade.

The global NFC market size was valued at $15,531 million in 2019, and is projected to reach $54,521 million by 2028, registering a CAGR of 14.8% from 2021 to 2028.[12] The growing amount of edge devices might bring a great increment of NFC market size.



6.3. Manufacturer

NXP is the leading manufacturer of NFC chips. It is by far the largest with around 60-80% of the market including Apple. The following are in descending importance:

- Broadcom (Samsung used them for Galaxy S4)
- Samsung Semiconductors
- TI
- ST Micro
- Inside Secure (sold their NFC business to Intel in 2011)
- Qualcomm

But ST Micro try hard to keep up with in the recent year. They published series of NFC reader and tag chips, and developed ST25 series, for dynamic NFC tags, which may be important for IoT edge devices to actively send their data back. In addition, we can see quite many application of chips from ST Micro in NFC Innovation Awards held by NFC Forum. For example, the application that won the first place in 2020 is an interactive smart holder for cars using ST's X-CUBE-NFC4 and X-NUCLEO-NFC04A1, a dynamic NFC/RFID tag IC expansion board which is based on the ST25DV04K NFC Type V/RFID tag IC with a dual interface 4 Kbits EEPROM that also features and I2C interface.

NFC/RFID tag ICs: Types and applications

ST25TV Series

ISO/IEC 15693
NFC Forum Type 5

Applications:

- luxury
- healthcare & wellness
- wine & spirits
- pharmaceutical
- consumer packaged goods
- clothing & footwear
- gaming
- sports

View products →

ST25TN Series

ISO/IEC 14443 Type A
NFC Forum Type 2

Applications:

- luxury
- healthcare & wellness
- wine & spirits
- pharmaceutical
- consumer packaged goods
- clothing & footwear
- sports

View products →

ST25TA Series

ISO/IEC 14443 Type A
NFC Forum Type 4

Applications:

- business card
- smart poster
- Bluetooth/Wi-Fi pairing

View products →

ST25

Dynamic NFC Tags			
ST25DV-PC	ST25DV-PWM	M24LR	M24SR
ISO15693 up to 53kb/s NFC type 5	ISO15693 26kb/s NFC type 5	ISO15693 up to 53kb/s	ISO14443-A 106kb/s NFC type 4
256Bytes buffer EEPROM 4-Kbit to 64-Kbit 40-year, 1Mcycles	EEPROM 2-Kbit 40-year, 100k cycles	EEPROM 4-Kbit to 64-Kbit 40-year, 1Mcycles	EEPROM 2-Kbit to 64-Kbit 200-year, 1Mcycles
Fast Transfer Mode 64-bit password E-harvesting Field detect	64-bit password Up to 15-bit PWM resolution	32-bit password E-harvesting Field detect	128-bit password RF disable Field detect
I²C 1.8V - 5.5V 1MHz	Up to 2 PWM outputs 1.8V - 5.5V 488Hz to 31.25kHz	I²C 1.8V - 5.5V 400kHz	I²C 2.4V - 5.5V 1MHz
Metering, Lightning Healthcare Home automation	Industrial	Metering Lightning Healthcare	Consumer Home appliance Wearable

7. Conclusion

7.1. SWOT

7.1.1. Strengths

- Interoperability and multifunctional
- Fast communication
- High security standards
- Highly promoted by associations such as NFC Forum

7.1.2. Weaknesses

- High investment on POS, SIM and devices
- Need to get a critical mass before to get foot hold in the market

7.1.3. Opportunities

- Many potential applications in different fields
- Development of a new ecosystem

7.1.4. Threats

- A lot of competitor technologies such as RFID and Bluetooth
- User resistance to changes

7.2. Future Scope

Since card-emulation mode in NFC can achieve physical object free, integration of ID-cards or passports with NFC devices may be possible application in the future. Security storage is essential and standard to modern smartphones, therefore, the mobile devices can be the storage area for personal information to provide user privacy and authorizing people to access the information.

With the feature of storing information related to device configuration, NFC can be a suitable solution to smart home network. By activating the NFC tag to configure the edge devices, all the home appliance control can be done with a mobile phone, making it fast and convenient.

However, although NFC Forum has standardized the data format and storage for security issues, when the technology is applied on mass devices in a network, every device can still become a point for the hackers to break into. Security will still be an important aspect when applying the technology.

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