



For many years, pervasive computing research has explored the potential benefits of creating a connection between the virtual world of the Internet, and the physical world we live in. The Near Field Communication (NFC) standard might, at last, be the technology that makes this vision a ubiquitous reality. This concept is sometimes referred to as the *Internet of things*.

then use them to receive a discount on the next related purchase. Further, you could print the contents of a digital camera on a nearby printer simply by tapping the camera against the printer case. These are just a few examples of applications that researchers have described, prototyped, and published since the mid-1990s, beneficially linking virtual information with physical devices through proximity.

Two technologies have been widely explored to enable these capabilities

- Both technologies let a reader obtain a coded reference to an Internet resource, either by storing the entire reference, or through a unique identifier that can be associated with the resource reference in a database. Each approach has pros and cons:

materials used and the expected business volume. Even at 10 cents, large volumes of tags add up to a significant amount of money.

On the other hand, QR code readers are sensitive to reader (usually a digital camera) orientation, and ambient lighting conditions and dirt, sometimes resulting in a difficult capture experience. However, RFID tag readers are fast and largely immune to the ambient conditions.

QR codes have achieved a degree of market penetration and currently appear on some types of advertising materials, in shop windows, and public places. This has been made possible because smartphones integrate digital cameras, and in recent years their adoption has been increasing, while at the same time camera-phone resolution has improved to accurately capture the spatial coding pattern used in a tag. Moreover, the processor has sufficiently high performance to execute the required image extraction several times a second, enabling the tag to be recognized in real-time, while being lined up with the camera view. In addition, many websites will encode your information into a QR code at no cost, or provide a short URL linking the QR code pattern with your data.

Unfortunately, RFID hasn't been integrated into daily use at the same scale, which leads us to question why. There are several possible explanations:

- The technology's use model is fundamentally less attractive.

- The business model can't support the cost of RFID tags.
- We haven't seen the right technology catalyst to kick-start the ecosystem.

Given the recent success of QR codes the first explanation is unlikely. The second is a distinct possibility, but we also know that costs will fall when the market size increases.

The most likely explanation is that there are very few mobile devices containing RFID readers. In fact, the retail industry has been the main adopter of RFID systems, with Wal-Mart and Tesco testing UHF RFID technologies to track and automate their inventory supply chains. Other RFID successes have been in Japan, where most phones integrate an RFID tag (usually compatible with the FeliCa standard) so customers carrying these devices can be automatically charged when they enter the subway system, and other pay-to-enter locations. When you consider that the world market for cell phones is now about 1.7 billion units per year,³ it's disappointing that so few support an integrated RFID reader.

THE NFC FORUM

In 2004, the NFC Forum (www.nfcforum.org) was created to bring existing mobile RFID standards efforts together and create a short-range communication capability that would enable a host of novel applications. It has been a long road for NFC with little market adoption since its inception, except for a few Nokia phones (Figure 2a) available in Europe but not marketed in North America. Today, NFC's future looks more promising with the development of Samsung's Nexus-S phone in 2010 (Figure 2b), which is now available in stores. There are also active rumors that one of Apple's next-generation iPhones will support NFC. This could be the kick-start the industry needs to develop a vibrant business around RFID information technologies.

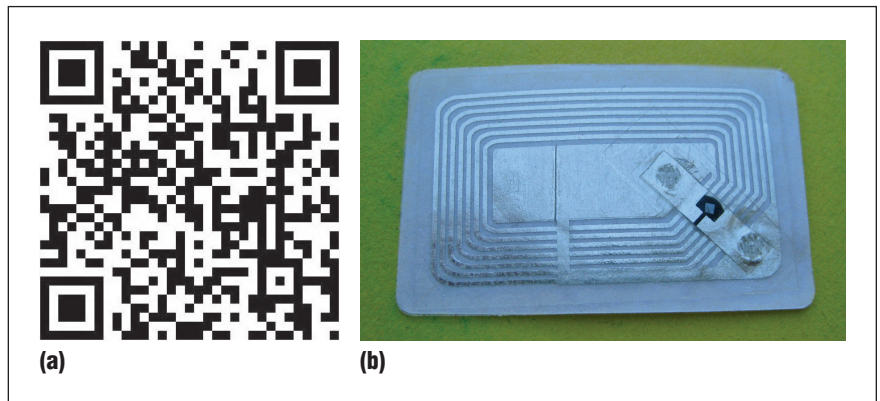


Figure 1. Technologies for linking physical objects with information on the Internet. (a) QR codes are optical tags printed on an object and contain information about an Internet resource. (b) Passive Radio Frequency Identification (RFID) tags, some of which are compatible with the Near Field Communication standard. They are less conspicuous, but more expensive, than QR codes.

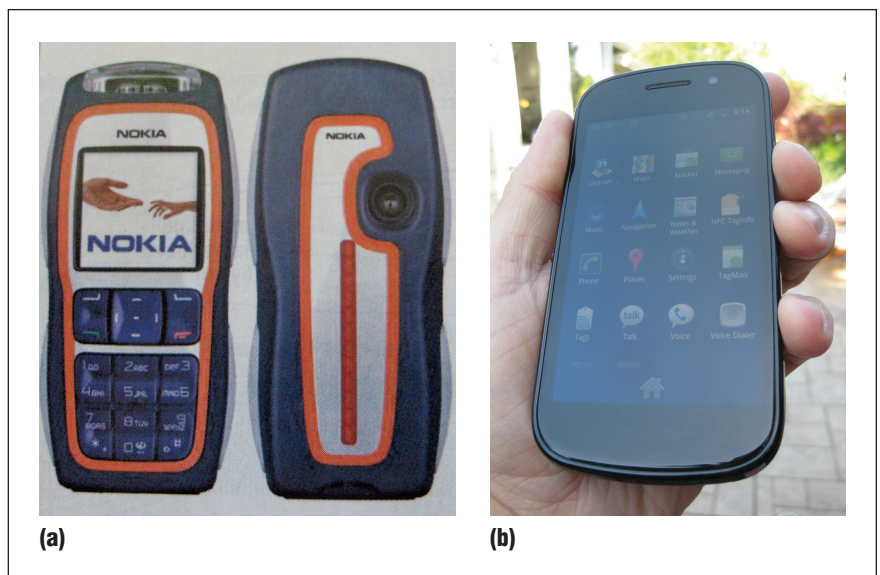


Figure 2. Mobile phones based on the NFC Forum's RFID standard: (a) the Nokia 3200, an early NFC cell phone; and (b) Samsung's Nexus S, an NFC-compatible smartphone.

FEATURES OF THE NFC STANDARD

The world of RFID includes many standards that operate at low frequency (LF), high frequency (HF), and ultra-high frequencies (UHF). Within each of these frequency domains are many standards that are incompatible with each other. NFC is a subset of these standards operating in the HF band at 13.56 MHz under the ISO 14443, ISO 18092, and FeliCa standards,

supporting a maximum data rate of 424 kbits per second (kbps) up to 10 cm. The NFC protocol not only supports communication between an active reader and a passive tag, but also allows for peer-to-peer communication between two active readers. Thus, an NFC-capable phone can both read a tag and receive and transmit data to another NFC-capable phone. Furthermore, tags can contain read/write memory, and today there are tag

products with 4 Kbytes of Flash. An NFC-smartphone can thus write arbitrary data into a tag as long as it fits in the available memory. When reading such a tag, a mobile device will obtain both a tag's unique identifier and, if requested, the corresponding data contents. To support secure write access, an unformatted tag is initially writable by everyone, but it allows a client to set a security key on internal blocks of data. This restricts tag writes to clients with access to these keys, and permits additional data to be written, or updated at a later time, with the knowledge that it's unlikely to be corrupted by other users.

Record Type Definitions

NFC data is transferred between a compatible reader and a target device (reader or tag) using an NFC Data Exchange Format (NDEF) message. An NDEF message can be composed of an unlimited number of NDEF records. Each record contains length and type information describing its intended function. Although the type information is extensible, a small set of record type definitions (RTD) are in common use.

The *text* type is the simplest form and enables basic text strings to be represented using ASCII or unicode, along with a parameter defining the language type.

The *unique resource identifier* type enables textual URIs to be encoded in a record. The defining header, for example, "http://www.," "https://," or "telnet://," can also be compressed into a 1-byte field in the NDEF header, reducing the size of the final URI text that a tag needs to store. An application receiving an NDEF record with a URI type can choose to automatically pass it to an application for processing—in the examples above, a Web browser or a telnet terminal client.

The *generic control* type encapsulates a recommendation to start an application, store the received data, or modify state on the target device, based on a received URL. As with all NFC

communication, this can be tag-to-device or device-to-device. It is intended that a client device should decide if the recommended action should go ahead automatically, or if it should require confirmation from a user.

The *signature* type defines a format for signing a set of NDEF records. This includes the signature algorithm and certificate types that can be used to create the signature.

The *smart poster* type allows for embedding multiple NDEF records in a tag, creating a self-describing "smart object." It builds on the RTDs described for URIs, text, and actions, enabling a tag to contain a title (text type), URI (URI type), an action recommendation, an icon represented as a MIME-type, and the URI type and target size that will need to be accessed and stored on the target device. For the smart poster RTD, only the URI record is a required field.

The smart poster RTD type provides the key ingredients for implementing many of the applications that are part of the vision for connecting the physical and virtual worlds. This standard provides the basic primitives for the Internet of things.

Connection Handover

In addition to associating information, NFC also supports a mechanism for connection handover to alternate wireless technologies. This capability addresses the problem that many existing wireless technologies face—that is, the set-up procedure tends to be complex. By using the more intuitive touch-to-connect mechanism, an NFC tag or P2P protocol can encode the necessary information to describe each participating device's capabilities, and, if compatible, create a secure link between them. This can include Wi-Fi, Bluetooth, or any other wireless standard that they have in common. This is attractive because NFC has only a limited data rate of about 424 kbps, whereas a modern Wi-Fi network supports hundreds of megabits per second.

The physical security of an intuitive touch-to-connect low-bandwidth side channel enables a shared secret to be established, playing to NFC's strengths. Once secure, a higher-bandwidth wireless channel can be established by passing the network address and channel keys for the alternate wireless technology, playing to the strength of wireless LAN technologies.

Financial Transactions

One of the unique applications opened up by NFC is the opportunity for proximate financial transactions. A future smartphone might double as your electronic wallet and replace your credit cards in a more integrated virtual form. This is not so far-fetched, as contactless credit cards have been in use for some time, and the underlying protocols already exist. Given that most people in the developed world no longer leave their homes without a cell phone in hand, it makes sense to expand a phone's capability further to include commerce, thus reducing the number of additional debit and credit cards that we need to carry.

However, despite these benefits, there are security concerns among the general public over contactless and mobile phone methods of payment. A survey reported in the *Daily Mail* (UK newspaper) in May 2011 found that 73 percent of people need more education on the technology before they are prepared to use it. A significant percentage also reported that they needed more reassurance that the system is secure, and some had already been put off of using contactless credit cards because of fears over fraud or identity theft.⁴ Managing the perception of proximate transactions, especially when it comes down to transferring money, might be as big a challenge as deploying a new technology in the first place.

This is a critical time for manufacturers that are thinking about including NFC in mobile devices. The NFC

standards and technical specifications are in place, and open source NFC stacks are available for Linux, Android, Windows, Win/Mobile, and embedded real-time operating system solutions (www.open-nfc.org). Samsung has made the first move with its Android NFC smartphone. It's perhaps only a matter of time before NFC becomes another "must have" feature for mobile devices. ■

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