NEC'S APPROACH TO Bluetooth

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Introduction

The short-range wireless communication specification known as Bluetooth is currently drawing considerable attention in a variety of application fields due to its ease of use and the size of its potential.

There are a myriad of device solutions for realizing Bluetooth. The basic configuration consists of the main system in which Bluetooth is to be used with an added RF IC and baseband (BB) LSI, which are controlled by firmware.

NEC has now developed a BB LSI for Bluetooth, the µPD72501, and has started work on an RF IC. In order to support customization of this BB, NEC also plans to develop a BB core and a single chip incorporating the RF block.

This article outlines and describes the Bluetooth technology, and introduces some possible device solutions for realizing this technology.

Outline of Bluetooth

1. Features of Bluetooth

The basic specifications of Bluetooth are shown in Table 1.

Bluetooth is a short-range wireless communication specification that uses the 2.4 GHz ISM band, which is a worldwide unlicensed frequency band. Devices that use the ISM band can be used without acquiring a specific license, provided certain conditions are met and certification is obtained.

The Bluetooth specification was established primarily for use in mobile devices, and is expected to contribute significantly to reductions in their size, power consumption, and cost. The maximum data transfer rate is a comparatively low 723 kbps, and the standard communication distance is 10 m (extendable to up to about 100 m).

The Bluetooth specification involves the creation of a "piconet" network with one master unit connected to up to 7 slave units, and depending on the case, other terminals can also be included to form an ad hoc type network. This feature is of major importance in mobile device applications. Because multiple piconets can be combined (forming a "scatternet"), communication becomes possible between an even larger number of Bluetooth terminals.

Bluetooth also supports telephone-quality voice communication (64 kbps) using an SCO (Synchronous Connection Oriented) link for real-time performance connection. With the SCO link, the communication time is reserved, and data is transmitted at periodic intervals. Compare this to the ACL (Asynchronous Connectionless Link) used for general communication, where the communication time is not reserved, and data is transmitted only when necessary.

The name Bluetooth is taken from the name of the Viking king responsible for the bloodless unification of Denmark and Norway more than 1000 years ago. The unification of these two countries is most likely intended as an analogous reference to the merger of the communication and PC industries.

2. Bluetooth system configuration

The overall Bluetooth system configuration is shown in Figure 1.

The "host" is the main system that is performing data transfer using Bluetooth. For example, if communication is being made between a cellular phone and a PC using Bluetooth, both the cellular phone and the PC are the hosts, and each control their own "host controller". These two host controllers each control an RF block and perform wireless communication.

The operation of the host controller is controlled by HCI (Host Controller Interface) commands sent from the host, which also transmits and receives data.

In the baseband block, a variety of data is added to the transmit data sent from the host, and that data is then sent to the RF block. During reception, the baseband block passes the received data on to the host.

Frequency band	2,402 to 2,480 MHz
Communication system	Frequency hopping type spectrum spread
Symbol rate	1 Mbps
Effective data communication speed	Up to 723 kbps
Output power	1 mW to 100 mW
Piconet	Network between one master unit and up to 7 slave units
Scatternet	Combined piconets
Voice communication	Synchronous communication packets supported
Error correction system	Correction using error correction coding (FEC), or screening using coding for error detection (CRC) and automatic re-send control (ARQ)

Table 1 Basic Bluetooth Specifications

2nd System LSI Engineering Department, Solution Engineering Division (Published May 2001)

In the RF (Radio Frequency) block, the transmit data is modulated to a wireless frequency and radiated as a radio wave. Received radio waves are demodulated and the resulting data is passed to the baseband block.

Figure 2 shows the software configuration. Processing at the lower HCI layer and below is performed by the baseband CPU, and processing at the upper HCI layer and above is performed by the CPU on the host side.

In the Bluetooth specification, the configuration of the upper layer software is determined based on the "profile" of each application, making it possible for units of the same type that support the same profile to communicate reliably with each other. There are two types of profiles: one that is essential for all Bluetooth units, and one that is specific to the characteristics of a particular unit. The number of profiles currently in existence is 13, with more expected to be added.

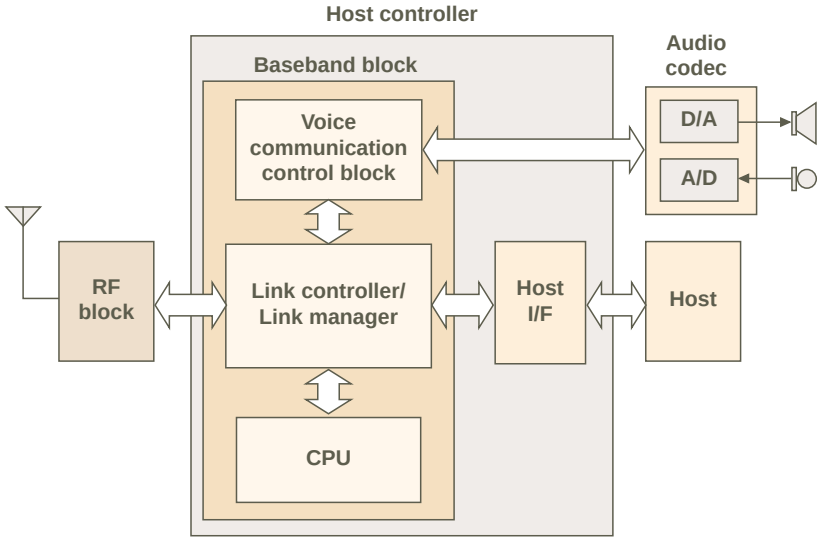

Fig. 1 Overall Bluetooth System Configuration

3. Application fields of Bluetooth

Bluetooth has already made an appearance in the PC peripheral equipment (PCs, PC cards, printers), cellular phone, and headset markets, and is expected to expand into other markets such PDAs, digital still cameras, and automotive electronics (car navigation, etc.) in the near future.

The increased convenience brought about by the incorporation of Bluetooth technology in all mobile and PC related devices such as notebook PCs, cellular phones, and PDAs will undoubtedly change the way we live.

Not only will conventional cable-based applications be replaced by:

- Wireless connection between mobile devices
- Automatic synchronization of data between fixed devices such as PCs and mobile devices in the office or home
- Wireless connection between mobile devices and modems, printers, etc.

But new applications may also appear, such as:

- Data exchange with a third-party mobile device
- Reception of local navigation information sent from stations, etc.
- Electronic purchasing using mobile devices

Since the Bluetooth specification is an

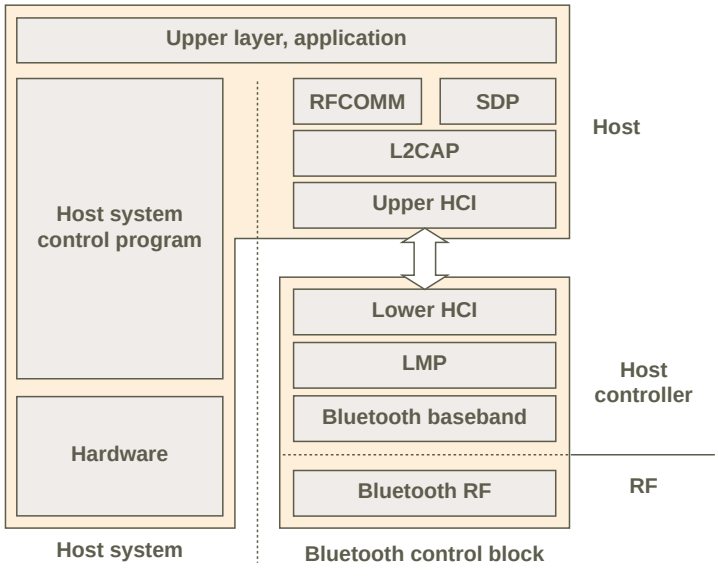

Fig. 2 Bluetooth Protocol Stack

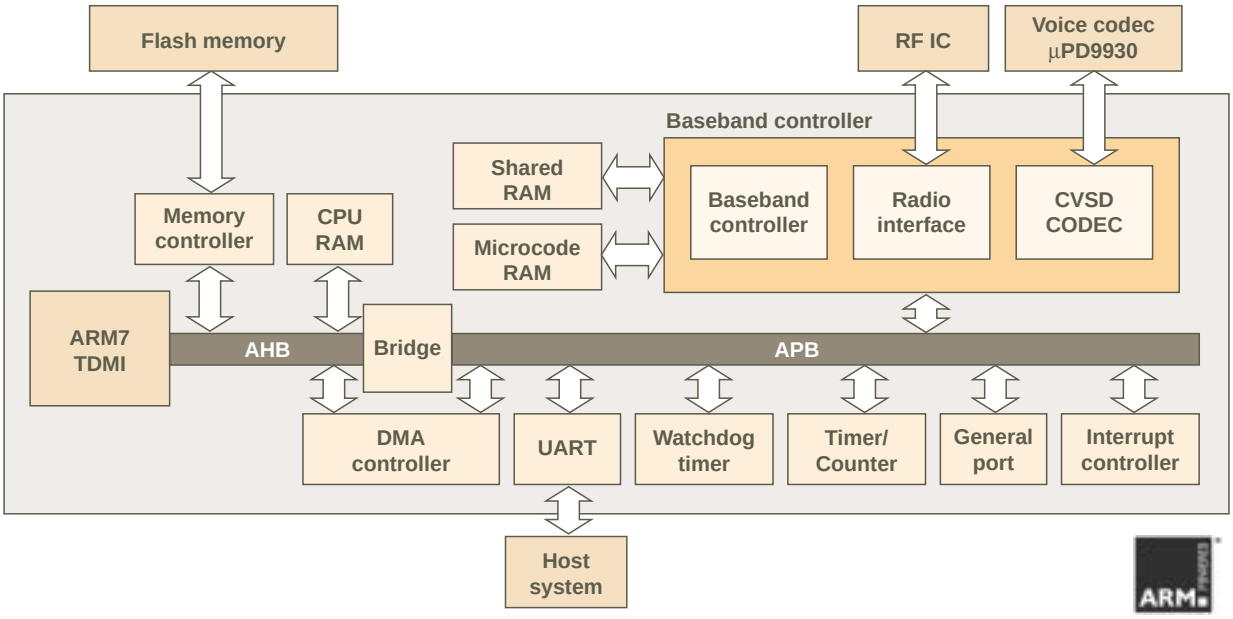

Fig. 3 Baseband LSI Block Diagram

international standard, communication between any Bluetooth units developed anywhere in the world will be possible, and data will be able to be exchanged and collated without cumbersome cables and connection procedures.

Of course, these benefits will apply not only to mobile devices, but to the connection of fixed devices in the home and office as well.

4. Bluetooth qualification system

Certain licenses are required to market products that incorporate Bluetooth technology.

At first, the Bluetooth qualification must be obtained. It is then necessary to obtain certification corresponding to individual countries' laws related to wireless and communication devices.

It is also permitted to obtain the Bluetooth qualification for individual components. For example, a partial qualification can be obtained by integrating an RF block, baseband block, and lower layer processing blocks in a module. By using this kind of Bluetooth module, customers only have to obtain a qualification for the Bluetooth upper layer and the necessary legal certification, and can thereby benefit from reductions in the time and resources required for development, as well as from reduced risk.

It is therefore expected that a Bluetooth module will initially be the popular form of this technology.

Baseband LSI

1. Basic operation of baseband (BB) LSI

The BB block provides a link for data exchange with the host. In other words, from the host's point of view, the role of the BB block is the same as that of a direct cable between the host and the partner unit.

In the BB block, it is necessary to add specific bits to transmit data to enable detection of errors in receive data, and add specific data for correcting errors. In this way, receive data can be passed on to the host with all errors removed.

Moreover, because the issue of security is particularly important in wireless communication, the BB block is also used to perform connection authentication to check the validity of the connection partner before start of communication, and to encrypt communication data to prevent misappropriation by a third party.

In wireless-related control, commands are continuously sent to the RF IC due to the use of a "frequency hopping" algorithm in which the communication frequency is changed at split-second intervals. The BB block is also responsible for controlling TDD (Time Division Duplex) operations, whereby transmit and receive operations are alternated based on time.

Voice communication is supported by means of a connection technique, the aforementioned SCO link, that guarantees a real-time performance by reserving communication time (slots) at periodic intervals. One kind of voice compression technique used in voice communications is CVSD (Continuous Variable Slope Delta) modulation.

2. Features of NEC's baseband LSI

In NEC's BB LSI μPD72501, Bluetooth communication processing is mainly performed by the baseband controller core (BBC). The

BBC employed by NEC is a product of the American company Tality Corporation (formerly Symbionics Corporation, Cadence Design Systems, Inc.), who are specialists in mobile communication LSIs such as DECT.

The block diagram of the µPD72501 is shown in Figure 3, and its features are outlined below.

- Compliance with Bluetooth Specification Ver1.1
  Immediate support of Ver1.1 is possible through firmware modification and micro programs (described below).
- Hardware-based link control
  The complex sequences accompanying link condition judgment are processed by a sequencer in the BBC using micro program control. Micro programs are downloaded from the external flash memory to the on-chip SRAM, and their contents are then read and executed by the sequencer. Being able to modify individual micro programs in this way provides enhanced support in the case of specification changes. All BBC operations, including those of the sequencer, are controlled by the CPU. Due to this hierarchical control structure, the CPU is not only able to process more complex sequences than those prescribed by the link manager protocol, but can also provide sufficient operability using only a small amount of power. In the µPD72501, the low-frequency operation (12 MHz) of the CPU and on-chip SRAM, as well as the employment of a function to stop the clock for individual blocks enables a significant reduction in power consumption.
  Operation using minimal power has also been achieved in the baseband core due to features such as clock stop for individual circuit blocks, low-power modes (sniff, hold, park), and low-frequency operation (3.2 kHz).
- Communication with one or multiple (up to 7) units possible
- Effective data rate: 723 kbps (max.)
- Range of power-save functions
  - Reset mode (power down by reset input): The device can be put in the reset state when not using Bluetooth, thus reducing current consumption to the µA level.
  - Standby mode (set by HCI command)
- Ultra-compact package
  As mentioned previously, from the viewpoint of usability, it is expected that Bluetooth will initially be popularized in a module form. Recognizing this, NEC has packaged the µPD72501 in an ultra-compact slim FPLGA (Fine-pitch Plastic Land Grid Array) package. Unlike a BGA, an LGA has no solder balls attached in grid form to the bottom of the package, enabling direct mounting on the substrate, and thus minimizing the mounting height (Fig. 4). This package has 112 pins, measures 8 mm x 8 mm, and is 0.83 mm thick. The height when mounted is no more than 1 mm.
- UART incorporating a 64-byte FIFO
  A 64-byte FIFO (First In First Out) buffer is used for both transmission and reception, enabling high-speed data transmission.
- Hang-up prevention via watchdog timer
  A watchdog timer is used to monitor software operations and take measures against hang-up to prevent the system lapsing into an uncontrollable state.
- General-purpose port controllable by HCI command
  A 4-bit general-purpose port is provided, each bit of which can be controlled independently by an HCI command.
- Standard interface with RF IC
  The Radio Interface is a circuit used to create control signals for an externally attached RF IC. Generally, the specifications of the interface between the BB and RF differ depending on the company, but some standard specifications have been proposed. NEC supports a general analog or digital interface.
- Support for voice communication
  In the µPD72501, a 1-channel SCO link has been realized with hardware. This link can support the two types of codecs prescribed in the Bluetooth Specification (log PCM and CVSD). Analog voice signals can be input and output simply by connecting a linear codec IC (µPD9930) externally.

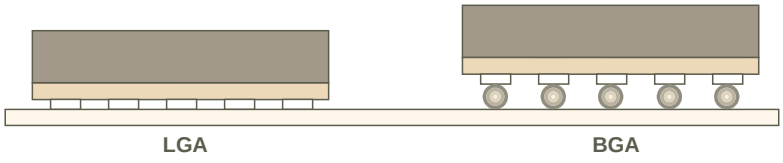

Fig. 4 Mounting of LGA and BGA

Bluetooth Solutions from NEC

The Bluetooth solutions available from NEC are shown in Figure 5.

Flash memory, an RF IC, and the voice codec IC µPD9930 (only required when voice communication is supported) are externally connected to the µPD72501.

For the lower layers, object codes are supplied as firmware from NEC, and can therefore be used embedded in the flash memory. For the upper layers, the four dedicated Bluetooth protocol stacks shown in Figure 2 (upper HCI, L2CAP, SDP, RFCOMM) and the simple OS that manages them are supplied as individual source files. In the future, NEC also plans to supply these as middleware corresponding to specific profiles.

It was mentioned previously that two licenses were required to market Bluetooth devices, but in the case of the µPD72501, obtaining the licenses has been made easier by the addition of the special HCI commands required for the qualification and certification tests.

Development of Bluetooth Solutions

As indicated before, it is possible to obtain a qualification for some components in a Bluetooth module. Because there is no guarantee that the manufacturer developing a Bluetooth device will have the necessary technological know-how for wireless applications, by using a Bluetooth module, manufacturers can eliminate the problems involved in designing wireless

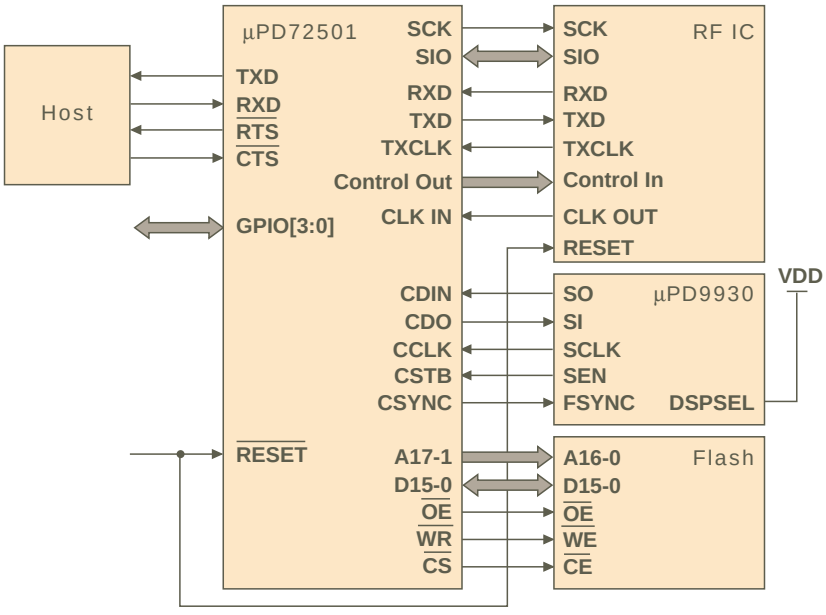

Fig. 5 Bluetooth Solution

circuits and also benefit by being able to obtain a qualification for the application system more easily.

Device solutions other than the general configurations currently in existence are also possible.

Figure 6 shows the overall Bluetooth function block and its respective parts, as well as the units for which a qualification is obtained.

Solution A is the general configuration at present. Layers below the HCI layer are configured and processed separately. The system as a whole requires at least 2 CPUs, for each of which separate memory is also required.

In solution B, a BBC is incorporated on the host system side. This means that a system can be configured with a minimum of one CPU. Separate memories are not required either as memory can be shared with the host. These features enable extremely high device usage efficiency. The functions required to realize this solution, such as LSIs that incorporate cores, total Bluetooth layer and application processing using one CPU, and lower layer software porting

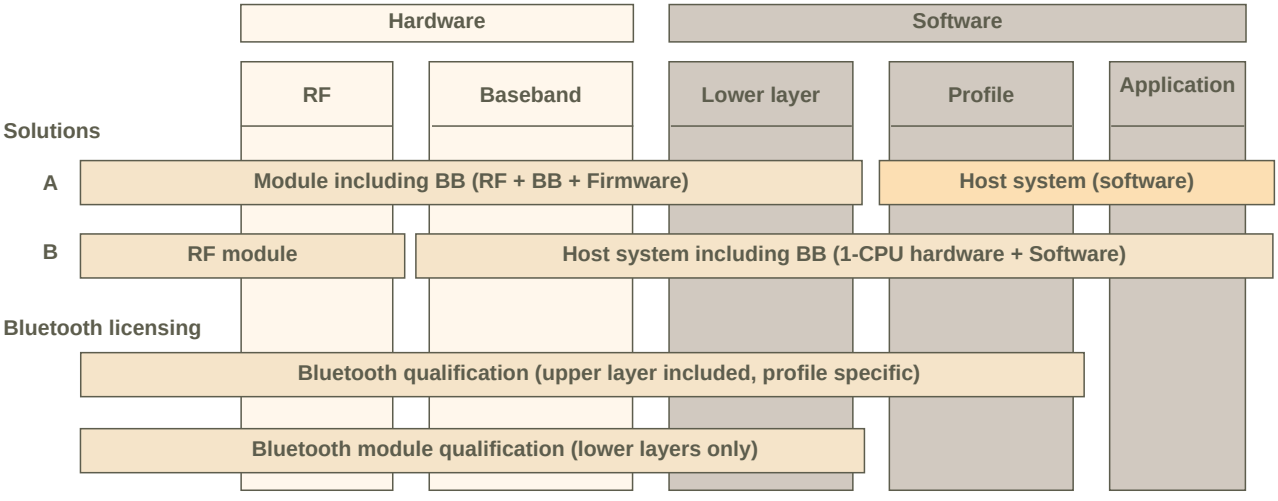

Fig. 6 Bluetooth Solutions and Licensing

to the host system, however, will require development that maximizes Bluetooth device and software technology. Nevertheless, due to its overall cost benefits, this configuration has great future potential. Another possibility is to customize the current BB LSI as a base (to which user logic and application software is added) using a one-CPU configuration.

As shown in Table 2, although these solutions have their advantages and disadvantages, both of them contain excellent features. It is to be imagined that in the near future it will be possible to select whichever solution best suits the requirements of an individual application.

Future Development

NEC is planning to develop application specific customized products (ASCPs) based on chip-shrink, low-power, and standard (ASSP) versions of the newly developed µPD72501, as well as single-chip products that incorporate an RF block.

By promoting development of other baseband core LSIs, NEC also aims to provide support for future specification revisions. A roadmap of Bluetooth products is shown in Figure 7.

NEC pledges to continue its pursuit of the ideal solution to a total Bluetooth system and maintain its policy of always offering its customers hardware and software configurations best suited to individual applications.

	Time Required to Obtain Qualification	Total Size	Development Hours	Cost Reduction Potential
Solution A	◎	○	◎	○
Solution B	△	○	△	◎

◎ : Excellent ○ : Good △ : Fair

Table 2. Solution Comparison

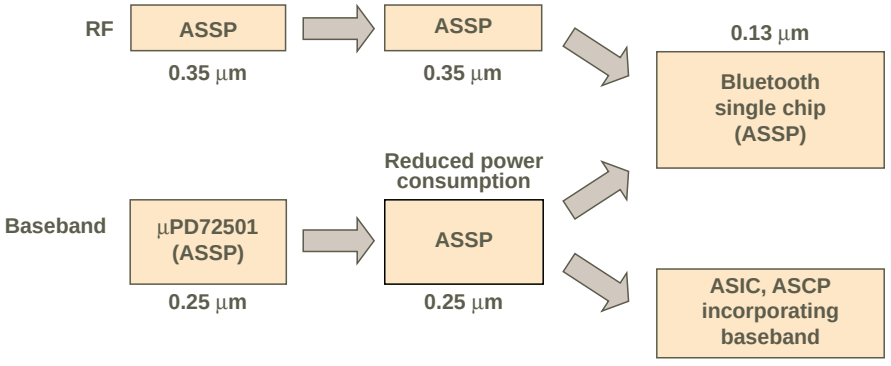

Fig. 7 Roadmap