In recent years, the upgrade cycle for vehicles has become increasingly longer. On the other hand, the cycle of developing and releasing multimedia devices in vehicles (hereinafter referred to as on-board devices) continues to become shorter, which causes a life cycle gap between vehicles and the on-board devices in those vehicles. Therefore, there is posed a problem with upgrading and equipping the on-board devices in vehicles to/with the latest functions. The technologies to solve this problem have been proposed but they only succeed in transferring a small portion of functions of the on-board devices to a network data center. As a result, the range of services offered is limited. In order to solve this problem, we recognized the advantage of mobile devices of which purchase cycle is shorter. We believed that the latest functions can be provided to the on-board devices by using a thin client system where almost all the functions of an on-board device are transferred to a separate mobile device and a network data center, and then we validated it. From the verification results, we concluded that this system can keep the functions of the on-board devices updated.
1 Introduction

FUJITSU TEN has developed functions of linking on-board multimedia devices (hereinafter referred to as on-board devices) with mobile devices since 2007. We developed the function that links a mobile device (cell phone) to an on-board device to transmit music in 2007, the function to transmit image and audio data, such as data from navigation software, in 2008, and a function to transmit a partial image, such as image from general information collecting software, in 2009.

This paper explains the results of our functional layout consideration for designing an on-board thin client system that we validated in 2008 with the purpose of establishing a link technology for transmitting image and audio data.

2 Purpose of Our Activities and Hypothesis

In recent years, the upgrade cycle for vehicles has become increasingly longer. On the other hand, the cycle of developing and releasing new on-board device products continues to become shorter. This poses a problem in the automotive industry, as it becomes increasingly difficult to upgrade the on-board devices installed in vehicles with the latest features.

![Product Cycle Gap](image)

Fig.1 Product Cycle Gap

 Technologies to solve this problem have been proposed, but these technologies only succeed in transferring control of a small portion of the functions of the on-board device to a remotely located network data center. As a result, the range of services offered is limited (such as in the case of navigation services dependent upon communication with a remote network data center). Focusing on the widespread use and the short upgrade cycle of mobile devices, our assumption was that by adopting a system layout that transfers the functions of the on-board device to a separate mobile device and a remote network data center, we could offer a system that doesn’t suffer from the service limitations of the aforementioned technologies, while offering the end user with an on-board device that provides the latest features. Therefore, we proposed the following hypothesis and proceeded to validate it.

[Hypothesis] By utilizing of the cutting edge features available in mobile devices, as part of an in-vehicle system, one can effectively keep the features of the on-board device up-to-date.

We expected the following benefit, as well:

- By driving on-board device prices lower, we can promote further market penetration of on-board devices.

3 Determination of Functions to be delegated to Outside of On-board Device

In order to allow the system to offer the latest features, most of the functions that were performed natively in the on-board device were delegated to an internet data center and a mobile device. Furthermore, we needed to determine where each function should be located and what information should be transmitted between the on-board device and the mobile device, as well as between the mobile device and the network data center. The layout which we adopted is as follows:

- **Conventional functional layout (Applications dependent upon communication with a network data center)**

![Conventional functional layout](image)

Fig.2 Concept of Thin Client System for On-board Device

- **New functional layout employed**

![New functional layout](image)

Fig.3 Functional Layout (above: conventional layout / below: layout employed)

Below, we outline the basic flow of two typical operations...
Functional Layout Considerations for Designing An On-board Thin Client System

A. Transmission of image and audio data from the mobile device to the on-board device
A-(1) The mobile device transmits image and audio data to the on-board device.
A-(2) The on-board device interprets the data received and extracts image and audio from it.
A-(3) The on-board device displays the image and/or plays the audio.

B. Performing on-screen user operations using the on-board device
B-(1) The on-board device reads and transmits the coordinate of the on-screen point that is pushed by the user.
B-(2) The mobile device interprets the received data and extracts the coordinate information.
B-(3) The mobile device executes the next process, such as processing the command required when the corresponding coordinate is pushed.

By adopting this functional layout which limits the degree of functionality required for the on-board device only to input/output functionality, while utilizing the latest features offered by mobile devices, we assumed that we could realize a method for effectively keeping the functionality of the system as a whole up-to-date.

4 System Configuration Validation and Overview of System I/F (Interface)

While designing the system to be validated, we needed to consider the following configuration issues:

4.1 Configuration Issues Encountered for the System to Be Validated

4.1.1 Selection of Mobile Device

Upon choosing a mobile device, we considered a wide array of options, such as portable media players, PDAs, cell phones, and laptop computers. However, for our purposes the mobile device in question needed to meet the following requirements, as our stated purpose was to validate a system which is capable of offering the latest features:

- Rich in terms of available applications
- Equipped with capability of updating applications

Therefore, we decided to use a cell phone, not only because it satisfies the above requirements, but also because of the deep market penetration of cell phones in Japan (one cell phone per person). Additionally, we also considered cell phones to be the optimal choice for our test configuration, as the system allows the user to control the mobile device via the on-board device, thereby indirectly preventing the user from using their cell phone during driving, which is prohibited by Japanese laws and regulations.

4.1.2 Selection of Applications to be used

There were many possible choices for the application to be used for the test configuration, including music player, hands-free operation, and web browser applications. By validating the system using an application which handles image and audio data that is updated regularly, we assumed that we could yield validation results that would also hold true for other applications. Therefore, we decided to use navigation software, as it satisfies the above conditions and is typically offered as a basic service of ITS.

4.1.3 Selection of Communication Method

Taking into account its convenience, bi-directional wireless communication capabilities and widespread use, we selected the Bluetooth protocol as the communication method between the on-board and mobile devices. We judged the Bluetooth protocol to be the best choice for our purposes because of its widespread use in the automotive industry to facilitate hands-free phone call capabilities.

We designed I/F between the on-board and mobile devices under the above conditions.

4.2 Outline of Input/Output Interface between On-board and Mobile Devices

4.2.1 Bluetooth Profile

Among the many profiles available for the Bluetooth protocol, which we selected as the communication method for our validation system, we decided to use SPP (Serial Port Profile). Our reasoning was that we required a profile that can send and receive various types of data, while taking into account the possibility of future changes of the communication method employed.

4.2.2 Communication Software between Devices

In order to allow for the on-board device and mobile
device to properly interpret the image and audio data, we were required to design and deploy additional communication software in both devices. The software designed includes functionality to interpret data and convert the data into commands during transmission of data between the two devices.

4.2.3 Data Packet Format between Communication Software

We designed a packet format based on the design concepts listed below:

- **Data should be formatted as text data to facilitate interoperability**
- The format should be limited to offer only the functionality required and should be simple, so that it can be applied to future uses.
- After a request command has been sent, the device sending the command should wait for a response signal (ACK) from the device receiving the initial command, before proceeding to the next sequence.
- Data that needs to be synchronized should be sent simultaneously as a composite command (e.g. audio that is specifically associated with a given image).

4.2.4 Data Transmitted between Devices

In regards to the detailed data sent and received between devices, we designated them as shown below:

- **Image data**
  We selected the JPEG format from the many image formats available because it was the image compression format with which the cell phone used for validation was compatible.

- **Audio information**
  We selected the MP3 format from the many audio formats available because it was the audio compression format with which the network data center used in the validation system was compatible.

- **User operation data**
  Although there are many types of user operation data that can be handled, we selected relative coordinate data in order to allow for a flexible, multi-purpose interface between the multiple devices.

- **Sensor data**
  We selected GPS data from the various types of data provided from external sensors. The reason we chose GPS data was because of the fact that this data is vital for navigation software (which is a basic ITS service). Furthermore, using GPS data made it much easier for us to verify that the cell phone navigation software was operating properly, during the validation process.

4.2.5 Functional Layout during Navigation Software Usage

The figure below shows the functional layout of the navigation software selected for validation in our testing:

![Fig.8 Functional Layout during Navigation Software Usage](image)

**New functional layout employed**

4.3 Outline of On-board Device System

The below figure shows the hardware outline of the trial on-board device used in our testing.

![Fig.9 Block Diagram of On-board Device](image)

The main elements of the on-board device are a SH-MobileR2R microprocessor (Renesas Electronics Corporation) and a complete module compatible to Bluetooth Ver. 1.2 on the main substrate, and their I/Fs are connected via UART.

4.4 Targets of Link Functions

We set functional targets as shown below:

- **Lapse time**: two seconds\(^5\) for an image to be displayed on the display screen of the on-board device after the image is output from the mobile device.

Under the above-mentioned conditions, we validated our hypothesis.

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* (1) Period of time within which navigation software can adjust the position of the vehicle, taking into consideration the lapse time of the image data transmission.
Functional Layout Considerations for Designing An On-board Thin Client System

The listed below are the evaluation results from the validation testing of a navigation application dependent upon communication from a network data center, under the aforementioned conditions.

### Table 1 Evaluation Results

<table>
<thead>
<tr>
<th>Category</th>
<th>Item</th>
<th>Point to be validated</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>System viability</td>
<td>Route guidance</td>
<td>Is there any problem with the response of image/audio output from the cell phone for position coordinates/travel information from the on-board device? (viability of the new functional layout)</td>
<td>○</td>
</tr>
<tr>
<td>Voice guidance</td>
<td></td>
<td>Is there any problem with the response of audio output for the location points that require voice guidance (response to information output which is sent unidirectionally)?</td>
<td>○</td>
</tr>
<tr>
<td>Response speed</td>
<td></td>
<td>Is there any problem with the speed of response output from the cell phone in response to the user operational input from the on-board device?</td>
<td>△</td>
</tr>
<tr>
<td>System expandability</td>
<td>Ease of entry for application vendors</td>
<td>Is the interface employed easy to use?</td>
<td>○</td>
</tr>
</tbody>
</table>

○: Good, △: Moderately bad, ×: Bad

Under the conditions set for this validation testing, from the viewpoint of system viability, although we found that the user operation response was slightly delayed, route guidance and voice guidance functioned without any noticeable delay. As a result, we were able to verify that there is no problem with the viability of this system (as for the route guidance, the system is capable of providing route guidance at a level that is sufficient for a driver to arrive at his/her destination). Furthermore, by specifying a simple interface which takes into account the possibility of future use for various applications, we were able to successfully validate the system without making major changes to the navigation software used for the validation. In other words, we can also say that application vendors will find the interface easy to be used and that there are no problems from a system extensibility standpoint.

Moreover, as for image transmitting time required for an image to be displayed on the on-board device after the image is output from the mobile device, the transmitting time varied from one image to another, but it took less than the target (20 seconds) for every image to be displayed.

Based on the fact that we were able to successfully provide new services with the navigation software used for the validation within the functional layout we propose, we expect this functional layout to work with other applications as well. As such, we can say that by using this system, the features offered by on-board devices can be kept up-to-date through compatibility with the latest features found in mobile devices.

### Problems Encountered

As mentioned above, we validated that the system can upgrade the on-board device to keep it compatible with the latest functions offered by mobile devices. From a merchantability standpoint, however, the following problems should be solved if this system is to be further developed for practical application.

#### 6.1 Compatibility to Various Mobile Devices

Image and audio formats, screen aspect ratio, and pixel count differ from one mobile device to another. It is necessary to further research methods to compensate for this difference when displaying on the on-board device screen. (We briefly examine below a case of difference in screen aspect ratios and pixel counts)

- **Current issues**: images output from the mobile device are clipped and resized to fit the screen size of the on-board device.
- **Ideal behavior**: depending on the screen layout desired, the area of the output image to be clipped is adjusted and enlarged/reduced for easy viewing.
- **Solution**: the on-board device can receive information of the image layout desired to be displayed, clip the image according to that information, and enlarge/reduce the image to the size that can be properly displayed on the on-board device screen.

Fig.10 Link Image

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6.2 Synchronization of Image and Audio Output in Communication between On-board and Mobile Devices

Here, we briefly examine measures to allow for synchronization of data that exceeds the communication bandwidth such as in cases where images and audio are simultaneously output or where multiple mobile devices are connected to the on-board device.

- **Current issues:** when data is larger than the communication bandwidth, it takes a long time to receive and synchronize it.
- **Ideal behavior:** images/audio that need to be synchronized are synchronized at a speed that does not cause the user an uncomfortable feeling.
- **Solution:** the availability of the communication bandwidth will be able to be constantly monitored and communication software will be able to arbitrate the packet flow in order of priority according to the availability.

6.3 Shorter Image Transmission Time

In general, an on-board device revises only a changed portion of an image. However, this employed system revises and transmits the whole image displayed on the screen regardless of the changed portion. As a result, a response to a user operation is slow, which confuses the user about whether the device is responding to his/her operation. Therefore, the time to transmit an image needs to be shorter.

- **Current issues:** a response to a user operation is slow. (e.g., Time required to display a reacted color in response to an operation of turning on the switch)
- **Ideal behavior:** a response to a user operation is quick.
- **Solution:** a partial image transmission method will be studied and validated in respect of transmitting only differences of images for shorter transmission time by reducing data volume to be transmitted.

The issues mentioned above are ones that can be solved by improving on-board and/or mobile devices. The issues below include various factors involving manufacturers and/or carriers of mobile devices. Therefore, solutions to those issues have not been fully discussed yet, but they are described below because they are important issues for users.

6.4 Efficient Usage of Mobile Device Battery Power

Applications that require map rendering or frequent communications to a remote network data center, such as navigation software, consume a large amount of electricity, posing a possible power issue to extended usage. Therefore, it is necessary to research a system that can limit power consumption.

- **Current issues:** the mobile device battery employed for the vilification only lasts for a little under 4 hours, when used with its backlight turned off while maintaining a persistent Bluetooth connection.
- **Ideal behavior:** the service should still work even if is used continuously throughout the day.
- **Solution:** it is necessary to conduct further research into power management methods that are appropriate to the amount of data communication handled between the on-board and mobile devices (such as power saving setting for modules). It is also necessary to review each process where power consumption may be reduced. For example, the amount of communication with the remote network data center is reduced (caching of processed data). Or, we will try to fundamentally solve the power issue by adopting a wireless power supply system.

By validating our proposed system, we were able to prove that new services could be made available by simply adding new applications to mobile devices rather than replacing or upgrading the on-board device itself. Furthermore, by taking advantage of the increasing availability of network connectivity, we can further adapt this approach to offer the following services:

- **Further contributions to ITS development**

  In addition to ITS information, by uploading sensor data collected by the vehicle, the system can use the data as probe data which can then be used for other applications (adaptation to services “unique to vehicles,” other than navigation, using data from sensors).

- **Seamless services**

  Taking advantage of the mobile device’s role as an information terminal that can be used both inside and outside of a vehicle, it is possible to apply our system to create new seamless information services. One possible service may allow the user to use, outside the vehicle, the information that the mobile device has received from the on-board device while those devices are connected with each other, or to use, when it is connected to the on-board device in the vehicle, the information that the mobile device has downloaded outside the vehicle.

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**Conclusion**

By validating our proposed system, we were able to prove that new services could be made available by simply adding new applications to mobile devices rather than replacing or upgrading the on-board device itself. Furthermore, by taking advantage of the increasing availability of network connectivity, we can further adapt this approach to offer the following services:

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