Sensor Application for Museum Guidance

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Abstract - This article examines the conditions for successful communication and power saving of sensor application for voice guidance in big museum halls. The system model consists of several piconets where some sensor nodes will provide location information to the server and also user information to the users' devices. Some possible technologies as Bluetooth, ZigBee and UWB will be compared in order to find the best one providing synchronization with the location of many individual visitors and voice guidance in real-time application.

1 Introduction

Electronic guidance via wireless devices could be used for museums according to some positioning models surveyed in number of papers in recent years [2], [4]. Among the most important requirements to such system is the location of the users' devices (notebooks or headsets) to be defined via some sensors and the collected data to be resent to a data base. When a certain piece of information is requested, alternatively data retrieval from it will occur. In case of voice guidance, a synchronization to the location of many individual visitors' headsets is necessary. Also the users should be able to manipulate the audio information or to request certain piece of information.
A simplified system model according to the client-server principle is investigated, whereas the users' headsets contact a server used to monitor the server devices and to supply the audio or data to be transferred as shown in fig 1. Several steps can be mentioned according to this model:

- an exchange of identification codes between the sensors and the users' devices in one hall,
- storage of the collected data at the sensor nodes,
- its transmission to the server,
- commands and data transfer from server to the sensor nodes,
- storage of the commands and data at the sensor nodes,
- retransmission of the commands and data from sensors to the headsets,
- commands' execution by the headsets,
- reply to the sensor nodes,
- storage of the reply at the sensors and
- retransmission of the reply to the server.

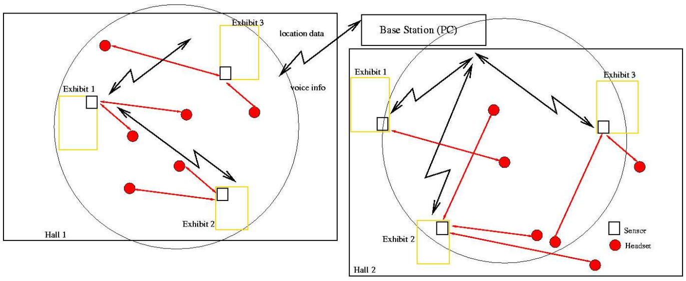

Figure 1: System Model for museum halls

Some problems can occur if the covered area of sensor nodes is not enough for all users devices which depends on the transmission power. This arises the next key problem in all battery devices: an efficient power control is required in order to insure a longer battery life. The transmission power should be negotiated between the devices while the lowest possible power consumtion will be reached. The accuracy of a positioning system dependes on the maximum range of the system which means the longer the range the higher the error rate will be. Also the delays between the sensor devices and users' devices are important, especially in case of moving users. The last but not the least - reliability of the link is required i.e. the bit error rate and packet loss have to be handled in appropriate way. Usually the authentication and encryption of the links are optional in order to provide secure communications.
The rest of the paper is arranged as follows: in the next section 2 a comparison of some wireless technologies (Bluetooth, ZigBee and UWB) is provided, whereas the conditions for successful communications are cosidered. Finally, some conclusions are given in section 3.

2 Comparison between sensor solutions

As one of the most widespread wireless solutions Bluetooth replaces all types of cables with a point-to-point or point-to-multipoint principle between fixed and portable devices. Single chips can be integrated. In the context of the already mentioned requirements the most important features of Bluetooth devices are as follows:

- Connection establishment - Before creating any connections in a piconet all devices are in standby mode, whereas each device periodically listens to a set of frequencies for inquiry scan messages each 1.28 s [1]. These messages are usually used for another devices discovery and contain the address of a new device. During a listening interval of about 18 slots a $625\mu s$ or 11.25 ms, the Bluetooth device listens to a single hop carrier and generates response messages. Completing the inquiry subroutine usually within 5.12 s, the page subroutine follows. It takes only 640 ms which means that the total time for establishing a connection between unknown devices is about 6 s. Otherwise only the second part of the described procedure i.e. the page should be carried out. In the worst case the maximum time for one position retrieval (inquiry scan) is about 19.2 s [4] which provides satisfactory performance for the examined case in a museum hall.

- Collision avoidance strategies - The applied frequency hopping (FH) provides a channels' arrangement within a 79 frequencies in a pseudo random way with a repetition interval of frequency hoppping sequences of more than 23 hours [5]. In this way can be avoided collisions between other transmitters taking a whole band in the same frequency range. In order to avoid the use of interfered frequencies only channels with higher quality marked

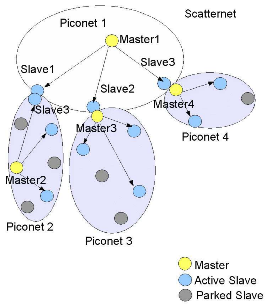

Figure 2: Scatternet of four piconets

as "good" can be used if optional mode AFH (Adapted Frequency Hopping) is accepted between devices supporting Bluetooth standard v.1.2. However, this assumes a regular channel state check and in time driven frequency hopping choice.

- Network topology - Multi-point connections can be established between Bluetooth devices and when two or more devices sharing the same channel form a piconet on the master-to-slave principle. The device created a piconet is assumed to be a master as it defines the frequency-hop sequences within a piconet. At the same time a master can participate in other piconet as slave on another hop sequence. Every frequency-hop sequence is derived from the master's address and phase. Therefore each slave should add an offset to its own clock in order to create the master's clock. The communication between the chips and the server as well as between the chips and visitors' headsets is carried on different frequency hops and in different time. It is assumed that the chips take part in piconet 1 as slaves of the Bluetooth server in order to resend some piece of voice information to the users. At the same time the sensors act as masters or slaves in another piconets of the visitors' headsets. In this way the number of active slaves in a scatternet can be significantly extended as shown in fig2.

- Power control - The transmission power control is mandatory for devices with transmit power over of 100 mW must and such devices should negotiate the lowest possible power consumtion. It is achieved in the means of appropriate link manager protocol (LMP) messages according to the received signal strength index (RSSI) values [1]. In order to save some power and also to increase the number of potential participants in a piconet some low power states as hold, sniff and park are defined. They are used to connect several piconets because of the limited number of active slaves. Maximum of seven slaves can be addressed within a piconet but each slave may participate in other piconets. A slave unit can get into hold mode for a defined time where only its internal clock runs, it keeps its address in the piconet and is still synchronized to the master. Another similar mode is sniff mode, where only the master can start transmission in previously specified sniff slots. A significant difference exists between these modes and park mode because a slave does not participate in data exchange but it remains synchronized to the master.

ZigBee solutions have been developed especially for monitoring and control of different devices where only data transmission is enabled. However one possible solution is to convert the voice information to data and to transmit it over PDAs [6].
Among the key features of this technology should be mentioned:

System parameter	Bluetooth	ZigBee	UWB
Principle	FHSS	DSSS	no carrier
Modulation	GFSK	OQPSK	PPM
Data rate, Mbps	$1-3$	$0.20-0.250$	$24-110$
Bit Error Rate	$1E-04@12.5dB$	$1E-04@0dB$	$1E-04@11.5dB$
Max. joint piconets	10	65000	4
Tx Power, mW	$2.5; 1; 100$	0.2	$18-25E-03$
Range, m	$10-100$	$1-75$	$10-200$
Active Mode, mW	$8-30$	92	4
Sleep Mode, mW	$6E-02$	$3E-03$	na
Battery Life, days	7-60	100-1000	360-1800

Table 1: Comparison between possible solutions

- Connection Establishment - In order to enumerate a new device (slave) in a ZigBee network only 30 ms are needed because of the smaller packets format. Usually the channel access time for active slave is 15 ms and the transition from sleep state to active state takes 15 ms too [7].
- Network Topology - A ZigBee network can be created according to the master-to-slave principle as well as to the peer- to-peer principle. In this context two types of devices are distinguished: FFD (Full Function Device) and RFD (Reduced Function Device) with reduced ROM or RAM. Thus many RFDs can be handled in a network without requiring them to be parked. A FFD can communicate RFDs as well as another FFDs i.e. it takes part in both types of topologies. In a star network it appears as network coordinator (Private Area Network - PAN Coordinator) where it executes the whole traffic. Due to some extended addresses of 64 bits a network coordinator can manage more than 65 000 networks.
- Power Control - Due to RSSI values the link quality can be estimated and the proper state (active or sleep) can be chosen whereas the power consumption in bothe modes is lower than in the appropriate states of Bluetooth devices (see Table 1). A transition from active to sleep mode of a node is carried out by the network coordinator within special time slots in analogical way to Bluetooth, whereas an information about the strength indication, clear channel assessment and dynamic channel selection is transmitted within the packets.

In contrast to the previous observed technologies the Ultra-Wide Band (UWB) Ultra-Wide Band technology is defined as short pulses low power transmission, where each channel can have a bandwidth of more than 500 MHz [3]. Due to the low power of Bluetooth transmitters of 1 mW such connections are possible only in the short range of 10 meters or optional with amplifier to 100 mW in range of 100 meters [1]. As for the ZigBee devices a range up to 100 m is enabled, whereas less transmit power is needed. For UWB devices as reference value is often given a data rate of 50 Mbps in radius of 10 m but the UWB high data rate version (UWB-HDR) improves the data rate to 110 Mbps in range of 10 m. The transimt power is less than for ZigBee devices which enables the longest possible battery life of UWB devices. The technologies Bluetooth and UWB may be applied in their emerging high data rate versions (Bluetooth 2 and UWB-HDR alternatively) which could increase the exchanged data rate within such a network. On the other hand the power consumption in both modes (active and sleep) of ZigBee devices is less than in the analogical modes of Bluetooth devices. Additionally the ZigBee technology has the best BER performance in low SNR environment [7].

3 Conclusions

Several technologies have been compared regarding their possible sensor application. Although Bluetooth is not the ideal solution it is the most spread and the cheapest one at the moment. However, the emerging ZigBee and UWB solutions promise quite better performance.

4 Acknowledgments

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