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PRINCIP KOMUNIKACIJE U *BLUETOOTH* BEŽIČNOJ PAN MREŽI THE COMMUNICATION PRINCIPLE IN THE BLUETOOTH WIRELLES PAN NETWORK

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Sažetak: *U ovom radu objašnjen je princip povezivanja i komunikacije u* Bluetooth *bežičnoj mreži.* Bluetooth *bežična tehnologija najpoznatiji je predstavnik mrežnih tehnologija u sve popularnijim osobnim mrežama (PAN).*

Ključne riječi: - *Bluetooth*
- bežična mreža
- pikonet

Summary: *This paper gives an explanation for connection and communication principles of the Bluetooth wirelles network. Bluetooth wireless technology is the most popular network technology for personal area networking (PAN).*

Key words: - *Bluetooth*
- wireless network
- piconet

1. UVOD

Porast broja i funkcionalnosti elektroničkih uređaja uz stalnu potrebu njihove međusobne komunikacije dovodi do još bržeg porasta broja potrebnih kabela. To je poprimilo tolike razmjere da je malo ljudi koji koriste računalo, a da nemaju na stolu i u ladicama nepreglednu šumu kabela za spajanje perifernih uređaja, mobitela, kamera, itd. Uz to, velika se pozornost pridaje i mobilnosti unutar radnog okruženja. U početku je to izvedeno pomoću infracrvene veze, ali ona ima nedostatke koji onemogućavaju mobilnost. To se prvenstveno odnosi na potrebu izravne optičke veze i male udaljenosti među uređajima. Za razliku od infracrvene veze radioveza odnosno radiovalovi prostiru se u svim smjerovima i prolaze kroz zidove i ostale nemetalne prepreke.

2. FREKVENCIJE

Bluetooth koristi industrijski, znanstveni i medicinski (ISM) frekvencijski pojas. Taj se pojas nalazi u spektru 2,4 GHz. Može se slobodno i bez licence ili naknade koristiti u većini zemalja pod uvjetom ograničene emitirane snage. ISM pojas ima širinu od 83 MHz i zato pruža dovoljno prostora za izbjegavanje smetnji koje dolaze iz drugih uređaja koji koriste određenu frekvenciju.

1. INTRODUCTION

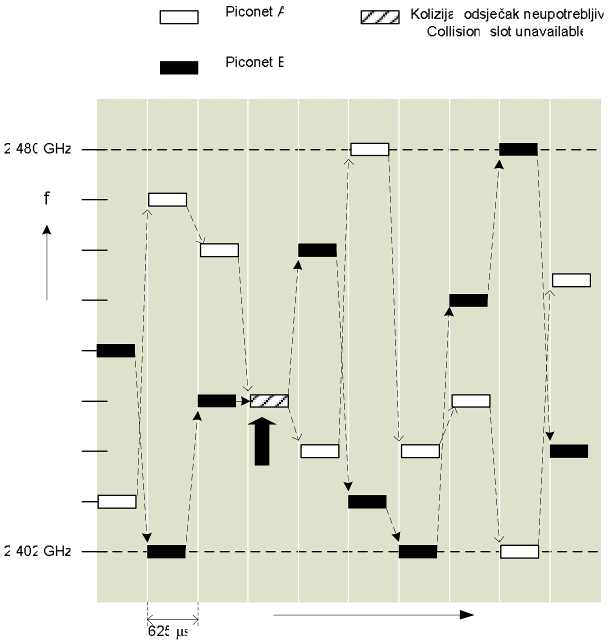
The increase in the number and functionalities of electronic devices in addition their mutual communication leads to an even greater increase of necessary communication cables. This has assumed such proportions that there are few people who use a computer and haven't got a bundle of cables for connecting peripherals, mobile phones, cameras, etc. In addition, lots of attention is being paid to mobility within the workplace. In the beginning, it was done via infrared links, but it has some disadvantages that preclude mobility. This especially refers to the need for a direct optical link and small distances between devices. As opposed to infrared link, radio link is transmits in all directions and passes through walls and other non-metal obstacles.

2. FREQUENCIES

Bluetooth uses the Industrial Scientific and Medical (ISM) frequency band. This band is located in the 2,4 GHz band. It may be used without any licence or fee in most of countries under condition of limited radiation power. The ISM band is 83 MHz wide and thus provides enough room to avoid interfering signals coming from equipment that uses a particular frequency.

To može biti WLAN, mikrovalna pećnica ili neki drugi izvor. Kako bi se izbjegli problemi s navedenim izvorima od kojih većina ima fiksne frekvencije, *Bluetooth* koristi tehniku širokog spektra. To znači da se frekvencija brzo mijenja (do 1600 puta u sekundi) na pseudoslučajni način. Rezultat je dovoljan broj slobodnih frekvencija da bi se postigla željena brzina prijenosa podataka. Taj se proces zove „preskakanje frekvencija u širokom spektru“ (FHSS). *Bluetooth* koristi 79 frekvencija u rasponu između 2,402 GHz i 2,480 GHz u razmaku od 1 MHz. Slika 1 prikazuje princip preskakanja frekvencija [4].

It can be WLAN, a microwave oven or some other source. In order to avoid problems with the mentioned sources, most of which have fixed frequencies, Bluetooth makes use of the spread-spectrum technique. This means that the frequency is changed rapidly (up to 1600 times per second) in a pseudo-random manner. The result is that enough interference-free frequencies are available to allow the desired data transfer to be achieved. This process is called Frequency-Hopping Spread Spectrum (FHSS). Bluetooth uses 79 frequencies in the range between 2,402 GHz and 2,480 GHz, with a separation of 1 MHz. Figure 1 shows the principle of frequency hopping [4].



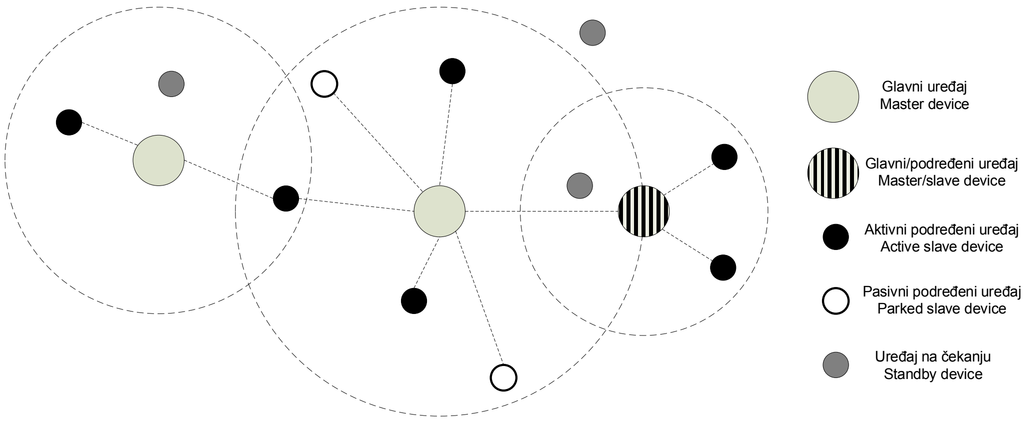
Slika 1. Preskakanje frekvencija [1]
Figure 1. Frequency hopping [1]

3. PIKONET I SKATERNET

Uređaji opremljeni *Bluetooth* modulima mogu nezavisno uspostaviti kontakt jedan s drugim pomoću tehnike preskakanja frekvencija. Radi sprječavanja međusobnog ometanja s ostalim *Bluetooth* uređajima u istom okruženju, koji bi mogli koristiti istu frekvenciju, redoslijed frekvencija određen je adresom i frekvencijom generatora takta onoga uređaja koji započinje povezivanje. Taj uređaj stoga postaje glavni uređaj u toj radiogrupi, dok su svi ostali sudionici označeni kao podređeni te se moraju sinkronizirati s glavnim uređajem. Do 8 uređaja može koristiti isti kanal.
Takva grupa tvori mrežu koja se zove ***pikonet*** (Slika 2).

3. PICONET AND SCATTERNET

Devices equipped with bluetooth modules can autonomously establish contact with each other, using the frequency-hopping technique. In order to prevent mutual interference with other Bluetooth devices in the same vicinity that might use the same frequencies, the frequency sequence is determined by the address and the clock rate of the device that initiates the connection. This device thus becomes the master device in this radio group, while all other participants are designated as slaves and must synchronize themselves with the master device. Up to 8 devices can use a single channel. Such a group forms a network that is called a ***piconet*** (Figure 2).



Slika 2. Komunikacijska topologija
Figure 2. Communication topology

U ovom kontekstu pojam „kanal" znači da svi sudionici pikoneta koriste isti redoslijed preskakanja, što znači da koriste isti redoslijed frekvencija. Budući da je svakom *Bluetooth* uređaju dodijeljena jedinstvena 48-bitna adresa, nije moguće da dva zasebna kanala imaju istu frekvenciju preskakanja.
Ako se nezavisno postave dodatni pikoneti na jednoj lokaciji, moguće je iskoristiti više od 8 *Bluetooth* uređaja uz velike brzine prijenosa podataka.
Podređeni uređaj koji radi u određenom pikonetu adresiran je u jednom vremenskom odsječku, a može se odazvati u sljedećem. Podređeni uređaj slobodan je sudjelovati u nekom drugom pikonetu u preostalim vremenskim odsječcima. Kako bi to učinio, namješta svoj prijamnik na frekvenciju drugog pikoneta odnosno na njegov fizički kanal i sinkronizira se s glavnim uređajem tog pikoneta. Višestruke bežične mreže povezane na taj način nazivaju se ***skaternet***. Sudari su izbjegnuti činjenicom da se podređeni uređaji sinkroniziraju s taktom glavnog uređaja. Skaternet više razine može sadržavati do 10 pikoneta pa je moguće napraviti mrežu od 80 uređaja. Čak i kad je jedan uređaj član svih 10 pikoneta, brzina će prijenosa podataka pasti za maksimalno oko 10% [3].

In this context, the term „channel" means that all members of the piconet employ the same hopping sequence, which means that they use the same series of frequencies. Since each Bluetooth device is assigned a unique 48-bit address, it is not possible for two separate channels to have the same hopping sequence.
By independently setting up additional piconets in the same vicinity, it is possible to use more than eight bluetooth devices in one location, with high data transfer rates.
A slave device operating in a particular piconet is addressed by a master device in one time slot (even numbered) and may respond in a subsequent time slot (odd numbered). The slave is free to participate in another piconet in the remaining time slots. In order to do so, it sets its receiver to the frequency to which the other piconet has just hopped and synchronizes itself to the master device of that piconet. Multiple wirelless networks that are interconnected in this manner are reffered to as ***scatternet***. Collisions are avoided by the fact that the slave devices synchronize themselves to the clock rate of the master. The higher level scatternet can contain up to 10 piconets, so that it is possible to build a network containing up to 80 devices. Even when a single device is a member of all 10 piconets, the data transfer rate is reduced by no more than around 10% [3].

4. FIZIČKI KANAL

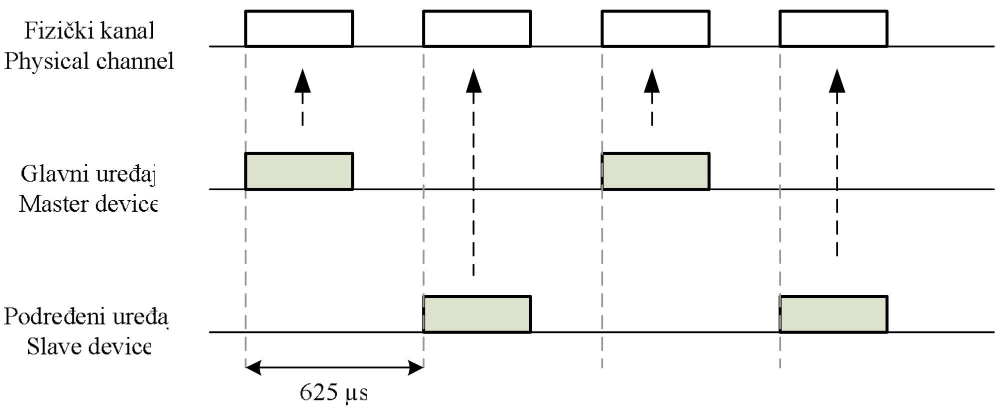
Fizički kanali obilježeni su RF (*Radio Frequency*) frekvencijom kombiniranom s vremenskim parametrima i ograničenim dometom. Preskakanje frekvencija koristi se za periodično smanjivanje utjecaja interferencija te za regulaciju.

4. PHYSICAL CHANNELS

Physical channels are characterized by an RF Radio Frequency) frequency combined with temporal parameters and restricted by spatial considerations. Frequency hopping is used to change the frequency periodically to reduce the effects of interference and for regulation purposes.

Dva *Bluetooth* uređaja koriste dijeljeni komunikacijski kanal za komunikaciju. Da bi se to postiglo, njihovi primopredajnici moraju biti podešeni na istu frekvenciju u isto vrijeme i moraju biti u dometu.
Budući da je broj frekvencija ograničen i da postoji mogućnost prisutnosti drugih uređaja u istom prostornom i vremenskom polju, mogućnost je kolizije velika. Kako bi se izbjegla kolizija, svaki prijenos započinje pristupnim kodom koji služi kao povezni kod uređaja spojenih na fizički kanal. Pristupni kod pripada fizičkom kanalu.
Kako bi podržao višestruke konkurentne zadatke, uređaj koristi vremensko multipleksiranje (TDM – *Time-Division Multiplex*) kanala. Na taj način uređaj prividno simultano djeluje među drugim uređajima ili pikonetima i još je pristupačan (može ga se otkriti i spojiti na njega). Preko fizičkih kanala promet se odvija prividno dvosmjerno po TDD (*Time-Division Duplex*) principu. *Master* i *slave* u ovom slučaju koriste svaki drugi vremenski odsječak kako je prikazano na slici 3.
Kad god je uređaj sinkroniziran s vremenom, frekvencijom i pristupnim kodom fizičkoga kanala, uređaj je spojen na taj kanal. Pristupni kod nalazi se u podatkovnom paketu [1].

Two Bluetooth devices use a shared physical channel for communication. To achieve this their transceivers need to be tuned to the same frequency at the same time, and they need to be in range of each other.
Given that the number of frequencies is limited and that many devices may be operating independently within the same spatial and temporal area, there is strong likelihood of collision. To mitigate the unwanted effects of this collision each transmission starts with an access code that is used as a correlation code by devices tuned to the physical channel. The access code belongs to the physical channel.
In order to support multiple concurrent operations the device uses time division multiplexing (TDM) between the channels. In this way a device can appear to operate simultaneously in several piconets, as well as being discoverable and connectable. Traffic over the physical channel takes place apparently in both dirrections using time division duplex (TDD). In this case, master and slave use every second time slot as shown in Figure 3.
Whenever the device is synchronized with the time, frequency and the access code of a channel, the device is connected to that channel. The access code is located in data packet [1].



Slika 3. Vremenski dupleks
Figure 3. Time-division duplex

5. LOGIČKI PRIJENOS PODATAKA

Moguće su dvije osnovne vrste prijenosa podataka u *Bluetooth* mreži. To su jednostruki, od točke do točke i višestruki, od jedne točke do više točaka.
Jednostruki su navedeni kao SCO (*Synchronous Connection Oriented*). Primarno su namijenjeni za prijenos glasovnih podataka. Potrebna je konekcija. Veza je stoga simetrična, što znači da je brzina prijenosa jednaka u obama smjerovima.

5. LOGICAL DATA TRANSMISSION

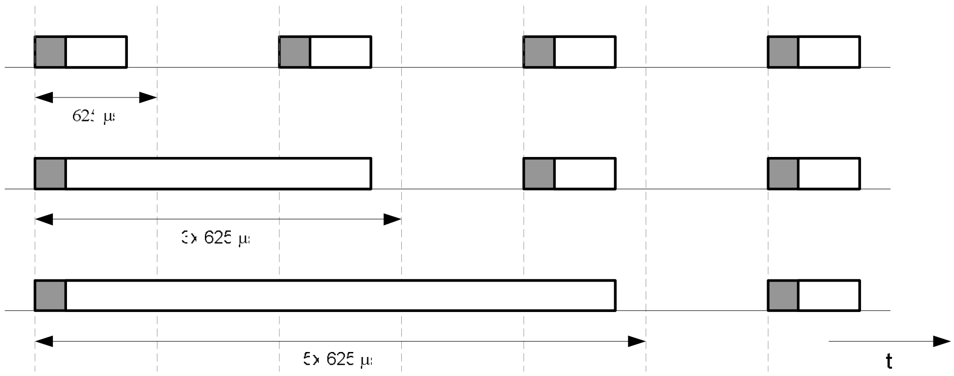
There are two basic types of data transmission in a Bluetooth network. These are point-to-point and point-to-multipoint.
Point-to-point transfers are referred to as SCO (Synchronous Connection Oriented). They are primarily intended to be used for voice data transmission. The link is thus symmetrical, which means that the data rate in both directions is the same.

Maksimalan je broj tih veza u pikonetu 3. Podređeni uređaj podržava dvije veze u isto vrijeme koje dolaze od različitih glavnih uređaja. Jedan može koristiti glasovne pakete ili miješane pakete glas/podaci. Brzina uzorkovanja za prijenos glasovnih podataka iznosi 64 kb/s, isto kao i za ISDN (*Integrated Services Digital Network*).

Višestruki prijenos podataka asinkron je i ne treba biti uspostavljena konekcija. Baziran je na podatkovnim paketima. Takve su veze navedene kao ACL (*Asynchronous Connection Less*). Master uređaj koristi tu vrstu prijenosa da bi komunicirao s nekoliko podređenih uređaja u isto vrijeme. Uz slanje paketa svim podređenim uređajima ta se vrsta prijenosa također koristi za slanje paketa specifičnom uređaju. Kako bi se povećala brzina prijenosa podataka, paket može zauzeti ne jedan već 3 ili 5 vremenskih odsječaka kao što je prikazano na slici 4.

A piconet has a maximum number of 3 SCO links. The slave device supports two links at the same time, originating from different masters. One can use the voice packets or mixed data/voice packets. The sampling rate for voice data transfers is 64 kb/s, the same as for ISDN (Integrated Services Digital Network).

Point-to-multipoint transfers are asynchronous and connection-independent. They are based on data packets. Such links are referred to as ACL (Asynchronous Connection Oriented). This type of transfer is used by the master device to communicate with several slave devices at the same time. In addition to being used for sending messages to all slave devices, this type of transfer is also used for sending data packets to a particular slave device. In order to increase the data transfer rate, a packet may use not only one but also 3 or 5 time slots, as shown in Figure 4.



Slika 4. Višestruki paketi
Figure 4. Multi-slot packets

Da bi se to omogućilo, preskakanje frekvencija se zaustavi, a frekvencija na početku prijenosa paketa ostaje ista u trajanju svih 3 ili 5 vremenskih intervala. To omogućava da se „rupe“ između susjednih odsječaka iskoriste za prijenos podataka. Zbog održavanja cjelokupne sinkronizacije preskakanje frekvencija se nastavlja onim redoslijedom koji bi i inače bio korišten.

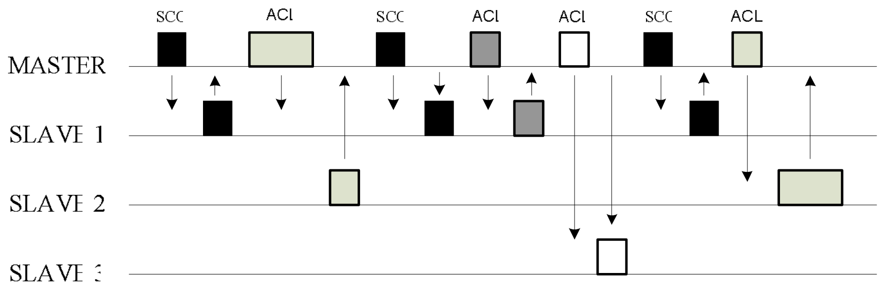
Prijenos podataka odvija se između podređenog i glavnog uređaja ili između podređenih uređaja.

Izravna komunikacija između podređenih uređaja nije moguća te se odvija preko glavnog uređaja koji za to šalje dozvole. Zaštita od pogrešaka vrši se isključivo nad ACL paketima.

Ako kod rezervacije odsječaka u slučaju SCO veze ostane slobodnih mjesta, glavni uređaj može ta mjesta iskoristiti za slanje prema drugim uređajima. Primjer toga prikazan je na slici 5 [3].

To make this possible, frequency-hopping is suspended and the frequency at the start of the packet transfer is maintained for the duration of 3 or 5 slot intervals. This allows the „holes“ between successive slots to be used for data transfer. In order to maintain overall synchronization, frequency hopping resumes on completion of the transfer with the frequency that would normally be used. Data transfers are carried out between slave and master and between slave devices.

Direct communication between slaves isn't possible and is carried out over a master device, which sends permissions to allow that. Error correction works only for ACL packets. If between reserved slots in the case of SCO links a few slots remain free, the master can use them to send data to other devices. an example of this procedure is shown in Figure 5 [3].



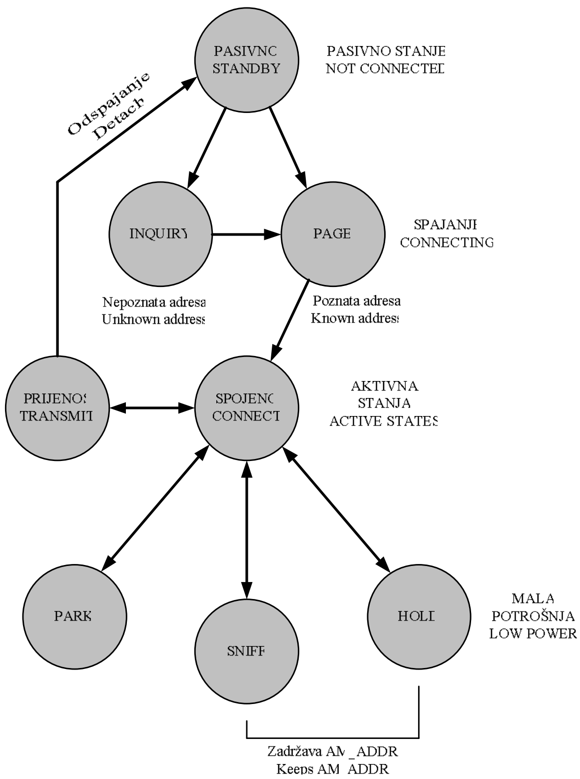
Slika 5. Komunikacija u rezerviranim i slobodnim odsječcima
Figure 5. Communication in reserved and free slots

6. STANJA PIKONETA

Bluetooth uređaji koji nisu članovi nijednog pikoneta, rade u pasivnom načinu rada, u kojem traže moguće povezivanje u njegovu najbližem okruženju svakih 1,28 s. To rade ispitujući 32 od mogućih 79 frekvencija koje su označene kao pobudni nosioci. Uređaj koji još nije spojen emitira poziv putem pobudnih nosilaca. Odgovor dobiva od ostalih uređaja u blizini.

6. PICONET STATES

Bluetooth devices that are not members of any piconet, operate in the Standby mode in which they search for possible transfers in their immediate environment every 1,28 s. They do this by testing 32 of the possible 79 frequencies, which are designated as wake-up carriers. A device that is not yet connected transmits a call via wake-up carriers.



Slika 6. Dijagram stanja Bluetooth uređaja [4]
Figure 6. Bluetooth device state diagram [4]

Nakon početnog dogovora, dva uređaja stvaraju pikonet, u kojem uređaj koji je započeo poziv uzima ulogu glavnog, te uspostavlja redoslijed skakanja frekvencija za taj pikonet, baziran na njegovoj 48-bitnoj adresi. Podređeni uređaj i bilo koji uređaj koji poslije pristupi tom pikonetu, sinkronizira se poslije s taktom glavnog uređaja.
Slika 6 prikazuje dijagram stanja *Bluetooth* uređaja. Počevši od pasivnog stanja kreće prema *Inquiry* stanju u kojem se otkriva drugi uređaj. U tom stanju emitira poziv kojem slijedi zahtjev za adresom. Jednom kad je adresa drugog uređaja utvrđena ili je već bila poznata u pasivnom stanju, uređaj prelazi u *Page* stanje. Nakon karakterističnoga kašnjenja od 0,6 s veza postaje aktivna (povezano stanje). Sada se podaci mogu prenositi (u stanju prijenosa podataka).
Nakon uspješnog prijenosa podataka, uređaj se može ili vratiti u pasivno stanje ili ući u jedan od triju načina rada niske potrošnje energije:
– prvi ekonomični način rada je *Hold*, u kojem uređaj ostaje aktivni član pikoneta (zadržava adresu aktivnog člana – AM_ADDR). Ako je potrebno, uređaj može odmah napustiti *Hold* način rada kako bi prenosio podatke. Glavni uređaj može prisiliti podređeni da ode u *Hold*, ali on može dobrovoljno ući u njega.
– u drugom ekonomičnom načinu rada poznatom kao *Sniff*, podređeni je uređaj programiran da periodički sluša pikonet komunikaciju ne bi li ustvrdio ima li nekih podataka za njega na čekanju.
– treći ekonomični način rada zove se *Park*. U tom načinu rada podređeni uređaj ostavlja pikonet i otpušta svoju AM_ADDR. Poslije toga ostaje pasivan i jedina je moguća aktivnost nastavak sinkronizacije s glavnim uređajem. Uređaj dobiva 8-bitnu adresu pasivnog člana, PM_ADDR. Taj način rada podržava maksimalno 255 uređaja [4].

After an introductory handshake, the two devices set up a piconet, in which the device that first issued the call takes on the roll of master. Based on its 48-bit address, it establishes the hopping sequence for the piconet. The slave device, and any other devices that later join this piconet, synchronize themselves to the clock rate of the master device.
Figure 6 shows a diagram of the state of a Bluetooth device. Starting from the Standby mode, it moves to the Inquiry state in detecting a second device. In this state, it transmits a general call followed by an address request. Once the address of the other device has been determined, or if this was already known in the Standby mode, the device transfers to the page mode. After a typical delay of 0,6 s, the connection becomes active (Connected State). Data transmission can now take place (in the Transmit Data State). After a successful data transmission, the device can either return to the Standby mode or enter one of three low-power (energy-saving) modes:
- the first low-power mode is the Hold mode, in which the device remains an active member of the piconet (it keeps the address of the active member – AM_ADDR). If necessary, the slave can leave the Hold mode in order to transfer data. The master can force a slave into the Hold mode, but a slave can also voluntarily enter the Hold mode.
- in the second low-power mode, the Sniff mode, the slave is programmed to periodically listen to the piconet to determine whether there is a data transfer waiting for it.
- the third mode is the Park mode. In this mode, the slave drops out of the piconet and frees its AM_ADDR. After this it remains passive, and its only activity is to maintain synchronization with the master. The device gets an 8-bit, passive member address, PM_AADR. This mode supports a maximum of 255 devices [4].

7. MODULACIJA I ZAŠTITA OD POGREŠAKA

Za svaki uskopojasni nosilac frekvencijskog preskakanja koristi se GFSK (*Gaussian Frequency-Shift Keying*) modulacija. S frekventnom devijacijom od 150 kHz širina nosioca uz atenuaciju -3 dB je 220 kHz. Ta prilično jednostavna modulacijska shema izabrana je da cijena primopredajnih integriranih krugova bude što niža.
1 mW (0 dBm) emitirane snage omogućava barem deset metara efektivnog dometa pod normalnim okolnostima. U nekim određenim slučajevima emitiranje većih snaga (do 100 mW ili +20dBm) dozvoljeno je uz emisije u širokom spektru, što omogućava domet do 100 m [5].

7. MODULATION AND ERROR HANDLING

Gaussian Frequency-Shift Keying (GFSK) modulation is employed for the frequency-hopping narrow-band carrier of each channel. With a frequency deviation of around 150 kHz, the -3 dB carrier bandwidth is 220 kHz. This fairly simple modulation scheme was chosen in order to keep the cost of the transceiver chips as low as possible.
The transmitted power, at 1 mW (0 dBm), allows for an effective range of ten meters under normal conditions. In certain special cases, the generation of higher field strengths (up to 100 mW or +20 dBm) is permitted with spread spectrum transmissions, which enables effective ranges of up to 100 m [5].

Bluetooth je RF komunikacijski sistem. U lošim RF uvjetima trebao bi se smatrati nepouzdanim. Kako bi se smanjio utjecaj smetnji, na svakoj razini postoji zaštita od smetnji.
Zaglavlje podatkovnog paketa koristi FEC (*Forward Error Correction*) u prijamniku i HEC (*Header Error Check*) da otkrije pogreške preostale nakon korekcije. Određeni paketi sadrže FEC za sadržaj. Nadalje, neki paketi sadrže CRC (*Cyclic Redundancy Check*).
U slučaju ACL logičkog transporta, rezultati dobiveni pomoću FEC koriste se za pokretanje ARQ (*Automatic Repeat reQuest*) protokola. To pruža poboljšanu pouzdanost retransmisijom paketa koji ne prođu provjeru u prijamniku. Moguće je modificirati te postavke kako bi se podržali paketi osjetljivi na kašnjenje na način da se isključi neuspješno poslani paket ako mu je korisno vrijeme isteklo.
Rezultirajuća je pouzdanost toga protokola ovisna o mogućnostima CRC i HEC kodova da otkriju pogreške. U većini slučajeva to je dovoljno. Doduše kod duljih paketa vjerojatnost je neotkrivenih pogrešaka prevelika za prijenos tipičnih aplikacija, pogotovo kod onih s velikom količinom informacija.
Broadcast veze zbog jednosmjernog protoka informacija ne mogu koristiti ARQ, ali prijamnici svejedno mogu detektirati pogrešku. Umjesto toga paketi se šalju nekoliko puta u nadi da će prijamnik ispravno primiti barem jednu kopiju. Unatoč tome pristupu nema jamstva sigurnog prijma pa se te veze smatraju nepouzdanima [3].

Bluetooth is a wireless communications system. In poor RF environments, this system should be considered unreliable. To counteract this, the system provides levels of protection at each layer.
The packet header uses forward error correcting (FEC) in the receiver and a header error check (HEC) to detect errors remaining after correction. Certain packet types include FEC for the payload. Furthermore, some packet types include a cyclic redundancy error check (CRC).
On ACL logical transports the results of the FEC algorithm are used to drive a simple automatic repeat request (ARQ) protocol. This provides an enhanced reliability by re-transmitting packets that do not pass the receiver's error checking algorithm. It is possible to modify this scheme to support latency-sensitive packets by discarding an unsuccessfully transmitted packet if the packet's useful life has expired.
The resulting reliability gained by this ARQ protocol is only as dependable as the ability of the HEC and CRC codes to detect errors. In most cases this is sufficient. However, for the longer packet types the probability of an undetected error is too high to support typical applications, especially those with a large amount of data being transferred.
Broadcast links have no feedback route, and are unable to use the ARQ scheme (although the receiver is still able to detect errors). Instead, each packet is transmitted several times in the hope that the receiver is able to receive at least one of the copies successfully. Despite this approach there are still no guarantees of successful receipt, and so these links are considered unreliable [3].

8. *BLUETOOTH* PAKETI

Baseband paket sastoji se od pristupnog koda (68 ili 72 bita), zaglavlja (54 bita) i korisnih informacija (0 – 2745 bita). U zaglavlju se nalaze kontrolne informacije o paketu, vezi i adresa odredišta.

Korisni dio sadrži poruku (informaciju) o trenutnom stanju, ako se radi o višem sloju protokola ili jednostavno podatke. Sadrži još i CRC bitove.

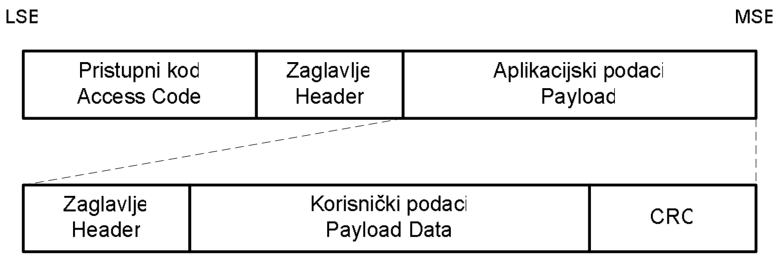
Postoje tri vrste pristupnoga koda. To su CAC (*Channel Access Code*), DAC (*Device Access Code*) i IAC (*Inquiry Access Code*). CAC služi za pristup fizičkom kanalu i izveden je iz 48-bitne adrese *Bluetooth* uređaja. DAC služi za pristup uređaju te se koristi kod stanja povezivanja (*page*). IAC se koristi kod pristupa funciji upita (*inquiry*) [3].
Na slici 7 prikazana je struktura paketa.

8. BLUETOOTH PACKETS

The baseband packet consists of an access code (68 or 72-bit), header (54-bit) and payload (0 – 2745 bits). The header contains the packet control information, information about the link and destination address.

The payload contains data on current states if this refers to higher protocols, or simply user data. CRC bits are also part of the payload.

There are three types of access code. These are the CAC (Channel Access Code), the DAC (Device Access Code) and the IAC (Inquiry Access Code). The CAC serves for accessing the physical channel and it is made of a 48-bit Bluetooth device address. The DAC serves for accessing a device and it is used for paging. IAC is used to access the inquiry function [3]. Figure 7 illustrates the packet structure.



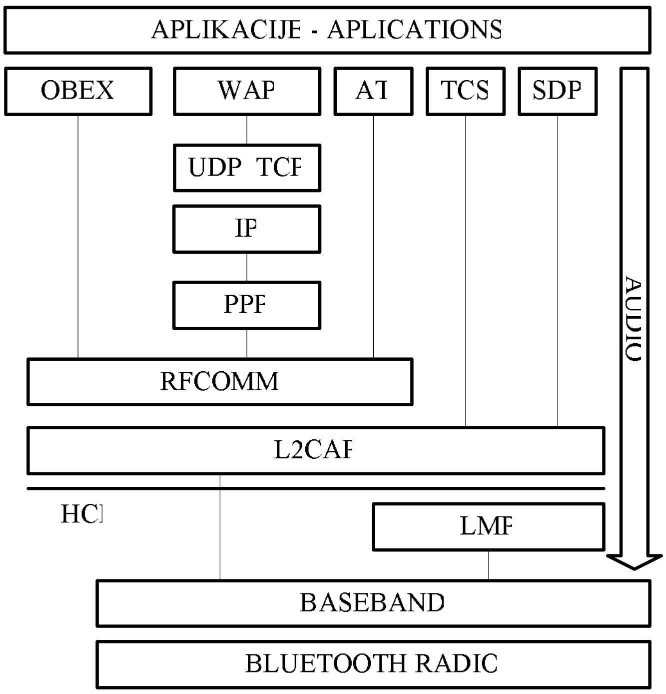
Slika 7. Struktura paketa [3]
Figure 7. Packet structure [3]

9. PROTOKOLNI STOG

Na kraju treba prikazati i sam protokolni stog čije su funkcije odgovorne za funkcioniranje ove tehnologije. Blok shema prikazana je na slici 8.

9. PROTOCOL STACK

Finally, there is a need to reveal the protocol stack itself, whose functions are crucial for the functioning of this technology. The block scheme is shown in figure 8.



Slika 8. Protokolni stog [5]
Figure 8. Protocol stack [5]

Radio je najniži sloj. Specifikacije njegova sučelja definiraju izlazne karakteristike, frekvencijske pojaseve, raspored kanala, dopuštene razine izlazne snage i osjetljivost prijamnika. Sljedeći sloj je *baseband*. On izvršava fizičku obradu podataka i kontrolu pristupa fizičkom mediju.

The radio is the lowest layer. Its interface specification defines the characteristics of the radio front end, frequency bands, channel arrangements, permissible transmit power levels, and receiver sensitivity level. The next layer is the baseband. It carries out physical and media access control processing.

To uključuje zadatke poput otkrivanja uređaja, formaciju veza i sinkronu i asinkronu komunikaciju sa signalizacijom. *Bluetooth* signalizacija mora izmijeniti mnoge kontrolne poruke s ciljem konfiguracije i upravljanja *baseband* konekcijama.
Te su kontrolne poruke u sastavu LMP-a (*Link Manager Protocol*). Funkcijski entitet odgovoran za izvršavanje obrade povezan sa LMP zove se *link manager*.
HCI (*Host to Controller Inerface*) specifikacija definira metodu komunikacije s *Bluetooth* kontrolerom neovisnu o sučelju. Programski stog na host procesoru komunicira s *Bluetooth* sklopovljem koristeći HCI komande. Budući da nije potrebno poznavati rad sklopovlja, programe protokolnog stoga moguće je jednostavno premještati s jednog *Bluetooth* integriranog kruga na drugi. HCI sloj je dio *Bluetooth* stoga, ali ne čini komunikaciju među urređajima i njegove se poruke ne prenose preko fizičkih veza.
L2CAP (*Logical Link And Adaptation Protocol*) moguće je promatrati kao sloj veze *Bluetooth* stoga. Obično su L2CAP i viši slojevi izvedeni programski. L2CAP dostavlja pakete dobivene od viših slojeva na drugi kraj veze. *Bluetooth* uređaji mogu uspostaviti L2CAP konekciju čim su u dometu. Tada uređaj u ulozi klijenta treba otkriti usluge koje pruža server. SDP (*Service Descovery Protocol*) definira načine na koje klijent može otkriti usluge i atribute tih usluga. Dizajn SDP-a optimiziran je za *Bluetooth*. Definira samo mehanizme otkrivanja, ali metode za pristupanje tim uslugama izvan su njegove domene.
RFCOMM definira metodu emulacije RS-232 konekcije preko *Bluetooth* zračne veze. RFCOMM podržava aplikacije koje koriste COM priključak za komunikaciju s hostom.
Ostali viši protokoli prikazani na slici 8 manje su bitni za rad samog uređaja i ovisni su o aplikacijama odnosno implementaciji sistema [5].

This includes tasks such as device discovery, link formation, and synchronous and asynchronous communication with signalization. Bluetooth signalization must exchange several control messages for the purpose of configuring and managing the baseband connections.
These control messages are part of the link manager protocol (LMP). The functional entity responsible for carrying out the processing associated with LMP is called the *link manager*.
The Host to Controller Interface (HCI) specification defines an interface-independent method of communicating with the Bluetooth controller. The software stack on the host processor communicates with the Bluetooth hardware using HCI commands. Since no hardware knowledge is needed, the Bluetooth stack software can easily be ported from one Bluetooth chip to another. The HCI layer is part of the Bluetooth stack, but it doesn't constitute a peer-to-peer communication layer since the HCI command and response messages do not flow over the physical link.
The logical link control and adaptation protocol (L2CAP) can be viewed as the Bluetooth's link layer. Usually, L2CAP and layers above it are implemented in software. The L2CAP delivers packets received from higher layers to the other end of the link. Bluetooth devices can establish an L2CAP connection as soon as they are in range of each other. A client device then needs to discover the services provided by the server device. The service discovery protocol (SDP) defines the means by which the client device can discover services as well as their attributes. The SDP design has been optimized for Bluetooth. It defines only the discovery mechanisms but the methods for accessing those services are outside its scope.
The RFCOMM defines a method of emulating the RS-232 connection over Bluetooth airlink. RFCOMM supports applications that use the COM port to communicate with the host.
Other higher-level protocols shown in Figure 8 are less signifficant for device core operation and they are application and implementation-dependent [5].

10. ZAKLJUČAK

Budućnost je komunikacija u bežičnom umrežavanju. Razlog je tomu sve dinamičniji pristup življenju, poslovanju, komuniciranju, itd. *Bluetooth* bežična tehnologija zbog svojih osnovnih karakteristika, malih dimenzija, niske potrošnje i cijene, može postati sveprisutna u malim elektroničkim uređajima kao što je to danas infracrvena tehnologija. Zbog svojih specifičnosti *Bluetooth* bežična tehnologija nije izravan konkurent već postojećim i dobro usvojenim tehnologijama. *Bluetooth* je komplementaran mobilnim mrežama druge i treće generacije i WLAN mrežama.

10. CONCLUSION

The future of communications is in the wireless approach. The reason for this lies in a more dynamic way of life, business, communication, etc. Because of its basic characteristics, small proportions, low consumption and price, Bluetooth technology can become omnipresent in small electronic devices the way that infrared technology is today. Bluetooth wireless technology isn't a direct competitor to other existing and well-adopted technologies. Bluetooth is complementary to second and third generation mobile networks and WLAN.

U širem kontekstu jedne mobilne veze možemo je promatrati kao zadnji bežični korak do korisnika. *Bluetooth* bežična tehnologija je i najpoznatiji predstavnik tehnologija za umrežavanje u sve popularnijim osobnim mrežama, *Personal Area Network* (PAN) i u tom području se može očekivati daljnja afirmacija.

In the wider context of a mobile network, it can be observed as the last wireless step closer to the user. Bluetooth wireless technology is also the most popular representative for personal area networking and in this field future affirmation can be expected.

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