THE PAGE ACCESS PROCEDURE IN BLUETOOTH

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ABSTRACT

The paper presents the mandatory paging of devices in the Bluetooth WPAN. There are stated the general principles of this communication procedure and its implementation in MATLAB. The page procedure is used to the connection establishment. The hopping sequence determined by the slave's address and the estimate of slave's native clock are the most important parameters in this procedure. The selection scheme of this sequence is implemented in the Graphical User Interface of MATLAB.

1 INTRODUCTION

The page procedure is used by a master device to activate a connection to a slave device. A device carrying out the page procedure is automatically the master of connection. The address of paged device is known to the master device but the devices are not FH (Frequency Hopping) synchronized. Therefore, the master device transmits two ID packets with the slave's DAC (Device Access Code) in every master-to-slave time slot at two different hop frequencies and awaits the response from the slave device in the slave to master time slots at corresponding frequencies. The page hopping sequence is determined by the LAP (Lower Address Part) address from the Bluetooth address of paged device. This page sequence contents 32 transmitting and 32 receiving unique frequencies constant for one address but the order of frequencies visiting is dependent on the estimated clock CLKE. The CLKE presents the estimated native clock CLKN of slave device. This estimate can be done base on the inquiry procedure. However, the estimate can be wrong therefore the synthesizer rate is increased to 3200 hops per second. The page sequence is divided into A-train and B-train, every with 16 hop frequencies. The A-train predicts the difference between the master's CLKN and slave's CLKN between -8·1.28 s and 7·1.28 s. The B-train predicts larger difference between clocks. The A-train (B-train) is chosen when the K_{OFFSET} parameter is set up to 24 (8). The single train is repeated N_{PAGE} times, then the second train is chosen. The change of train is made by adding 16 (decimal notation) to the current value of K_{OFFSET}. The number of repeating is depended on SR mode.

The page scan state is entered by the slave device in order to it could be paged. In this communication procedure, the slave device listens to its DAC at single hop frequency during the page scan window $T_{WPAGESCAN}$ last. The page scan window has to cover 16 page

frequencies. Then the single hop frequency is changed. The period of change is 1.28 s. It corresponds to the $CLKN_{16-12}$. The page scan sequence agrees with 32 master's transmitting frequencies. The phase in the sequence is dependent on the slave's CLKN.

When the slave device receives its access code, it enters the slave page response state and transmits its ID packet at the frequency 625 μs after the ID packet from the master device was received. Then the slave's $CLKN_{16-12}$ is frozen and the FHS (Frequency Hopping Synchronization) packet arrival is awaited. The FHS packet can be already received 312.5 μs after the slave's ID packet was sent to the master. If the FHS packet is received, the slave device returns the response. However, if the FHS packet does not arrive, the slave device will enter the page scan state. During the slave response procedure, the page response sequence is used. This sequence agrees with 32 master's receiving frequencies.

After the slave's response is received, the master's CLK_{16-12} is frozen and the master page response state is entered to send the FHS packet to the slave. The FHS packet is always sent at the start of time slot. In the next time slot, the master awaits the response to the FHS packet from the slave. If the response does not arrive the master repeats the FHS packet sending until the response arrives or the timeout is exceeded. If the second variant comes, the master will enter the page state. If the response to the FHS packet is received, the master sends the POLL packet at the frequency determined from the channel hopping sequence. The connection is established.

The principles of page communication procedure described above are illustrated in Fig. 1.
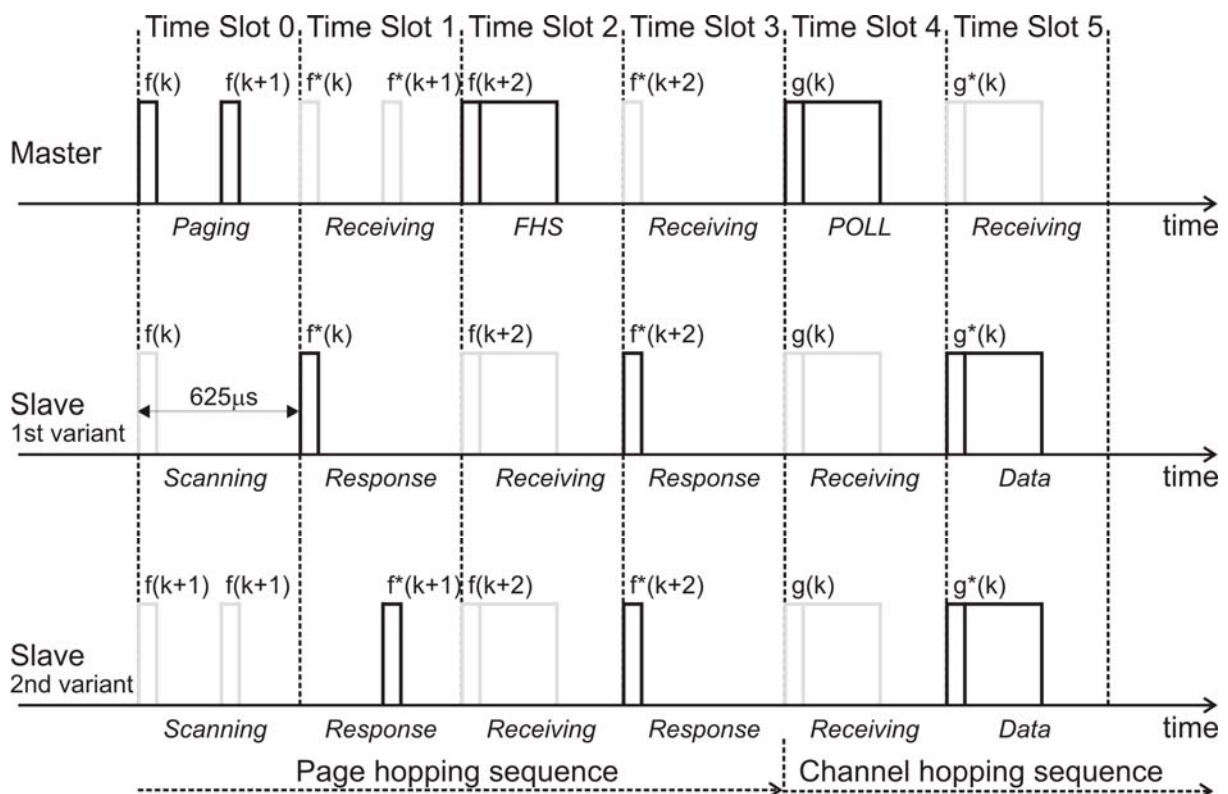
Fig. 1: *The process of page communication procedure*

2 PAGE HOPPING SEQUENCE IN MATLAB

The page hopping sequence is generated base on the selection scheme illustrated in Fig. 2. The address A is constructed from the particular bits of the slave's LAP address. The length of LAP (A) is 28 bits ($A_{27\text{-}0}$). The X input determines the phase in the sequence and is expressed by the following equations:

$$Xp_{4-0} = \left(CLKE_{16-12} + K_{OFFSET} + \left(CLKE_{4-2,0} - CLKE_{16-12}\right)\bmod 16\right)\bmod 32 \qquad (1)$$

$$Xps_{4-0} = CLKN_{16-12} \qquad (2)$$

$$Xprm_{4-0} = \left(CLKE^*_{16-12} + K^*_{OFFSET} + \left(CLKE^*_{4-2,0} - CLKE^*_{16-12}\right)\bmod 16\right)\bmod 32 \qquad (3)$$

$$Xprs_{4-0} = \left(CLKN^*_{16-12} + N\right)\bmod 32 \qquad (4)$$

The parameter Xp/Xps/Xprm and Xprs corresponds to the page/page scan/master page response and slave page response sequence. The CLKE presents the master estimated clock of the slave device and the CLKN presents the slave's native clock. The parameter N is the counter. In the master case, the initial value is set to 1 and is increased each time $CLKE_1$ is set to 0. This corresponds to the start of a master transmitting time slot. In the slave case, the initial value is set to 0 and is increased after each slave's response sending. The symbol * presents the frozen value of clock.
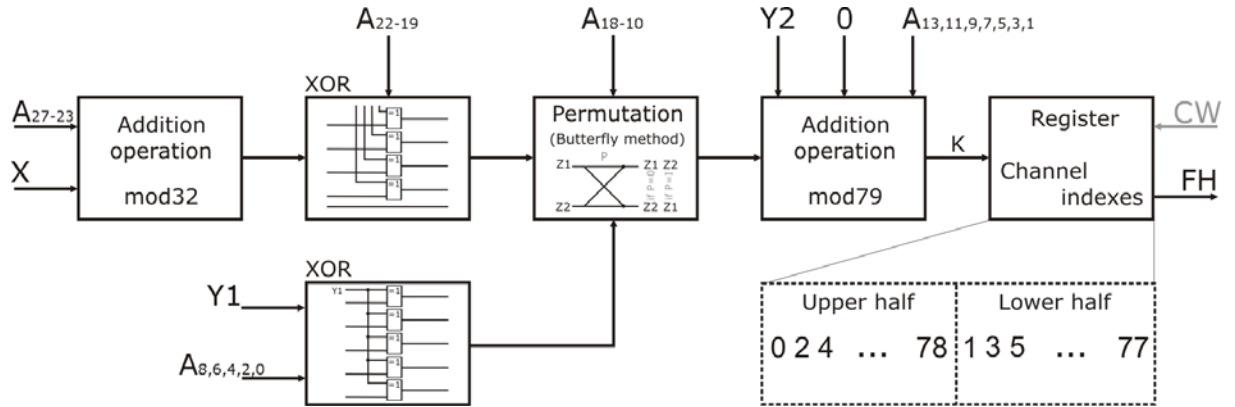
Fig. 2: *The page sequence selection scheme*

In Tab. 1, there are stated the values of control inputs to the selection scheme. The Xp input is described above, the Y1,Y2 inputs make a difference between the master-to-slave time slots and slave-to-master time slots.

Mode	Master		Slave	
	Page	Page Response	Page Scan	Page Response
Xp	$Xp_{4\text{-}0}$	$Xprm_{4\text{-}0}$	$Xps_{4\text{-}0}$	$Xprs_{4\text{-}0}$
Y1	$CLKE_1$	$CLKE_1$	0	$CLKN_1$
Y2	$32\text{x}CLKE_1$	$32\text{x}CLKE_1$	0	$32\text{x}CLKN_1$

Tab. 1: *The values of Xp, Y1 and Y2 inputs in a page procedure*

3   PROGRAM FOR THE BLUETOOTH PAGING MODELING

By the implementation of page procedure into MATLAB, there were applied some simplifying conditions for the first time implementation. It will be extended next time. The connection establishment is finished when the slave device sends the response.

The slave's address is set up in hexadecimal notation. The setting has to be confirmed. The random clock initial value option set up the master's CLKN and slave's CLKN to various random values. If the second option is chosen, the clocks could be user defined. The input parameters can be checked below the clocks setting. The procedure will be started if the start button is pressed. The program progressively generates the hop frequencies (for the master and slave) and draws them into the graphs. The device receiving is illustrated as a cross at corresponding frequency in the graph. In the first graph, there are illustrated the page and master page response procedures. The page scan procedure is illustrated in the second graph. The values at y axes don't express the transmit power in dBm but are only illustrative. The program can be also traced or can be user interrupted by the stop button pressing. The 32 hop segment for the specific page state is possible to display using popup menu.
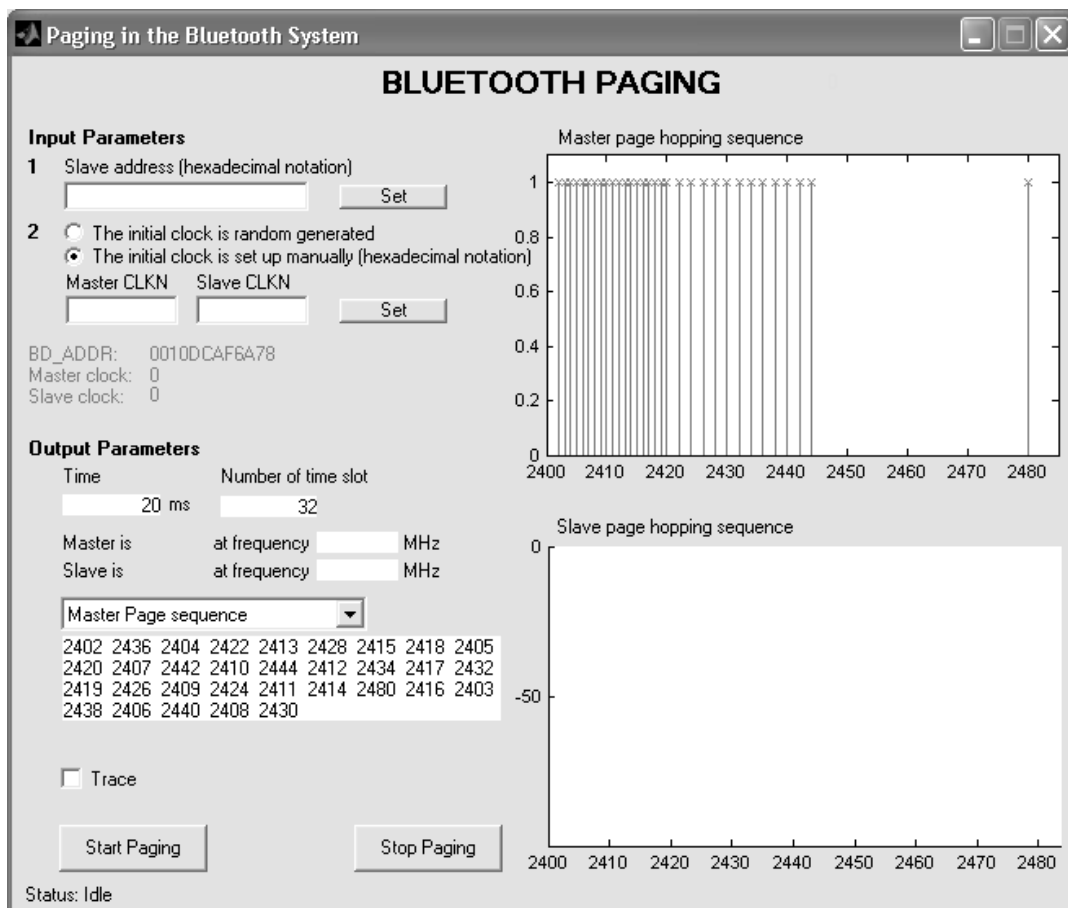

Fig. 3:   *The program for the Bluetooth page procedure simulation*

4   CONCLUSION

The time of connection establishment is mostly influenced by the page procedure last. Therefore, it's desirable to short the last this procedure. Several possibilities, how to make it, are offered there. It is possible e.g. to changed the X input calculation, the page scan window last, the response sending and etc.

The creation of page procedure model is the first step to the experiments continuing. Next time, this page procedure model will be replenished with all communication procedures like the inquiry procedure and connection procedure.

REFERENCES

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[3] HUMUSOFT: Creating Graphical User Interfaces. Help in MATLAB