10 CHANNEL CONTROL

10.1 SCOPE

This section describes how the channel of a piconet is established and how units can be added to and released from the piconet. Several states of operation of the Bluetooth units are defined to support these functions. In addition, the operation of several piconets sharing the same area, the so-called scatternet, is discussed. A special section is attributed to the Bluetooth clock which plays a major role in the FH synchronization.

10.2 MASTER-SLAVE DEFINITION

The channel in the piconet is characterized entirely by the master of the piconet. The Bluetooth device address (BD_ADDR) of the master determines the FH hopping sequence and the channel access code; the system clock of the master determines the phase in the hopping sequence and sets the timing. In addition, the master controls the traffic on the channel by a polling scheme.

By definition, the **master** is represented by the Bluetooth unit that initiates the connection (to one or more **slave** units). Note that the names ‘master’ and ‘slave’ only refer to the protocol on the channel: the Bluetooth units themselves are identical; that is, any unit can become a master of a piconet. Once a piconet has been established, master-slave roles can be exchanged. This is described in more detail in Section 10.9.3 on page 121.

10.3 BLUETOOTH CLOCK

Every Bluetooth unit has an internal system clock which determines the timing and hopping of the transceiver. The Bluetooth clock is derived from a free running native clock which is never adjusted and is never turned off. For synchronization with other units, only offsets are used that, added to the native clock, provide temporary Bluetooth clocks which are mutually synchronized. It should be noted that the Bluetooth clock has no relation to the time of day; it can therefore be initialized at any value. The Bluetooth clock provides the heart beat of the Bluetooth transceiver. Its resolution is at least half the TX or RX slot length, or 312.5 µs. The clock has a cycle of about a day. If the clock is implemented with a counter, a 28-bit counter is required that wraps around at 2^{28}-1. The LSB ticks in units of 312.5 µs, giving a clock rate of 3.2 kHz.

The timing and the frequency hopping on the channel of a piconet is determined by the Bluetooth clock of the master. When the piconet is established, the master clock is communicated to the slaves. Each slave adds an offset to its native clock to be synchronized to the master clock. Since the clocks are free-running, the offsets have to be updated regularly.

The clock determines critical periods and triggers the events in the Bluetooth receiver. Four periods are important in the Bluetooth system: 312.5 µs, 625 µs, 1.25 ms, and 1.28 s; these periods correspond to the timer bits CLK_0, CLK_1, CLK_2, and CLK_{12}, respectively, see Figure 10.1 on page 93. Master-to-slave transmission starts at the even-numbered slots when CLK_0 and CLK_1 are both zero.

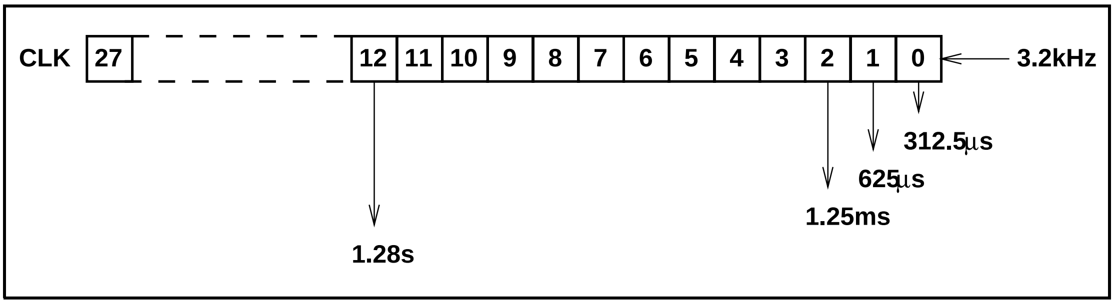

Figure 10.1: Bluetooth clock.

In the different modes and states a Bluetooth unit can reside in, the clock has different appearances:

- CLKN native clock
- CLKE estimated clock
- CLK master clock

CLKN is the free-running native clock and is the reference to all other clock appearances. In states with high activity, the native clock is driven by the reference crystal oscillator with worst case accuracy of +/-20ppm. In the low power states, like **STANDBY, HOLD, PARK** and **SNIFF**, the native clock may be driven by a low power oscillator (LPO) with relaxed accuracy (+/-250ppm).

CLKE and CLK are derived from the reference CLKN by adding an offset. CLKE is a clock estimate a paging unit makes of the native clock of the recipient; i.e. an offset is added to the CLKN of the pager to approximate the CLKN of the recipient, see Figure 10.2 on page 94. By using the CLKN of the recipient, the pager speeds up the connection establishment.

CLK is the master clock of the piconet. It is used for all timing and scheduling activities in the piconet. All Bluetooth devices use the CLK to schedule their transmission and reception. The CLK is derived from the native clock CLKN by adding an offset, see Figure 10.3 on page 94. The offset is zero for the master since CLK is identical to its own native clock CLKN. Each slave adds an appropriate offset to its CLKN such that the CLK corresponds to the CLKN of the master. Although all CLKNs in the Bluetooth devices run at the same nominal rate, mutual drift causes inaccuracies in CLK. Therefore, the offsets in the slaves must be regularly updated such that CLK is approximately CLKN of the master.

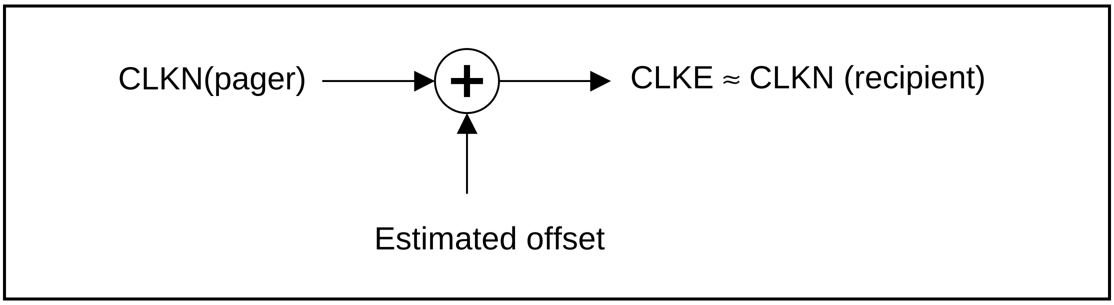

Figure 10.2: Derivation of CLKE

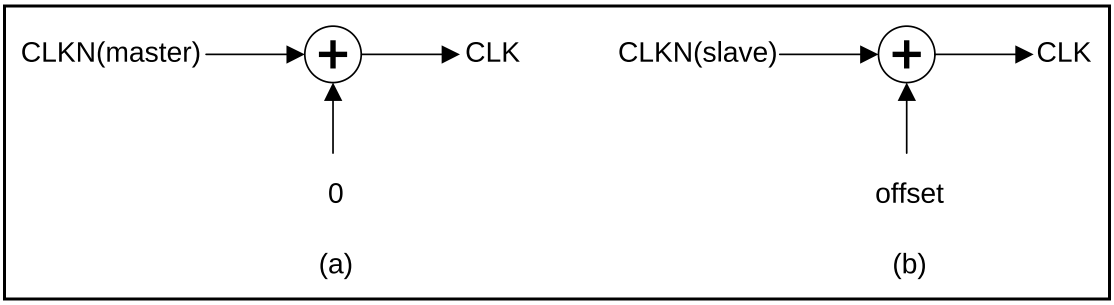

Figure 10.3: Derivation of CLK in master (a) and in slave (b).

10.4 OVERVIEW OF STATES

Figure 10.4 on page 95 shows a state diagram illustrating the different states used in the Bluetooth link controller. There are two major states: **STANDBY** and **CONNECTION**; in addition, there are seven substates, **page**, **page scan**, **inquiry**, **inquiry scan**, **master response**, **slave response**, and **inquiry response**. The substates are interim states that are used to add new slaves to a piconet. To move from one state to the other, either commands from the Bluetooth link manager are used, or internal signals in the link controller are used (such as the trigger signal from the correlator and the timeout signals).

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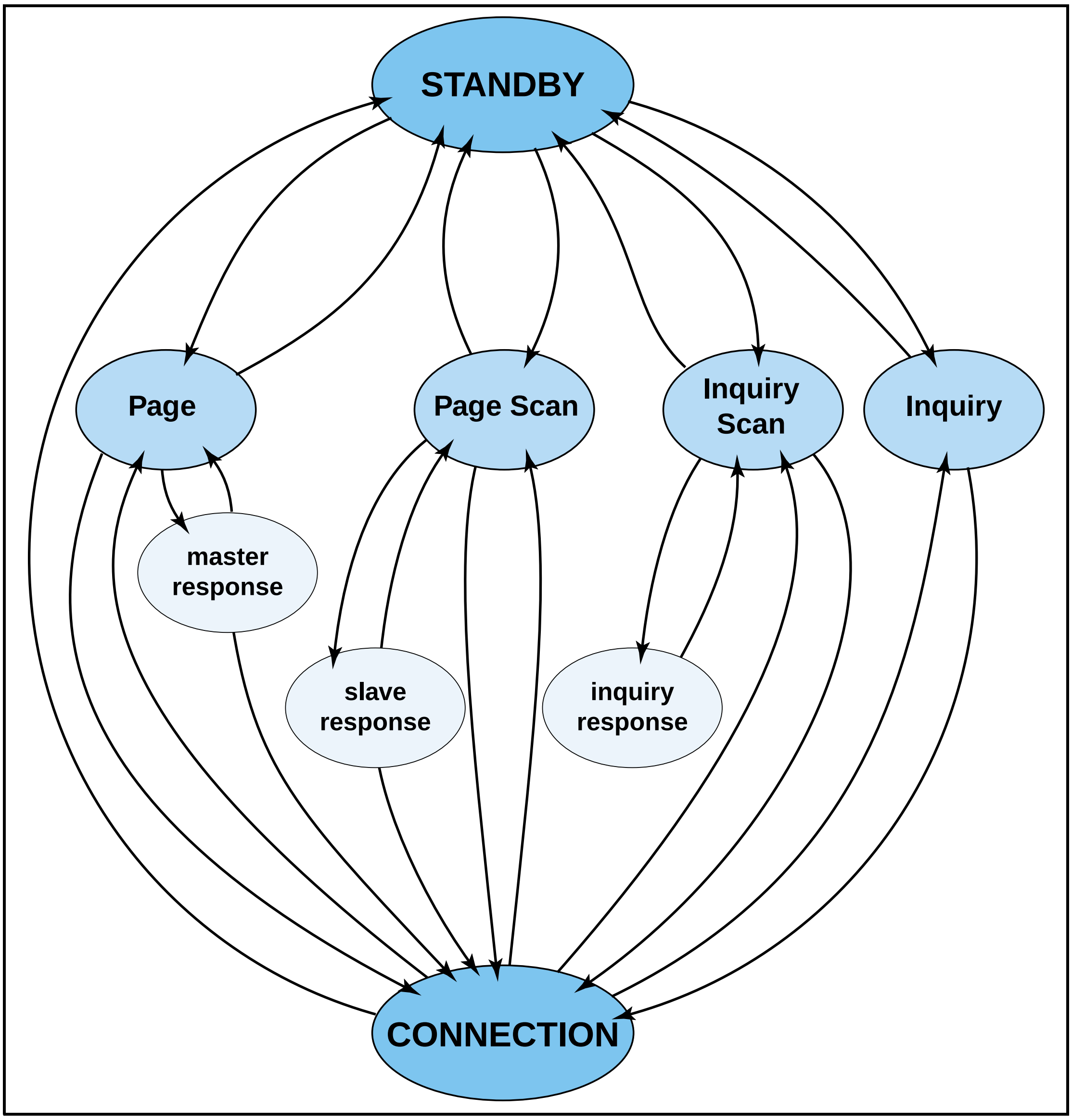

Figure 10.4: State diagram of Bluetooth link controller.

10.5 STANDBY STATE

The **STANDBY** state is the default state in the Bluetooth unit. In this state, the Bluetooth unit is in a low-power mode. Only the native clock is running at the accuracy of the LPO (or better).

The controller may leave the **STANDBY** state to scan for page or inquiry messages, or to page or inquiry itself. When responding to a page message, the unit will not return to the **STANDBY** state but enter the **CONNECTION** state as a slave. When carrying out a successful page attempt, the unit will enter the **CONNECTION** state as a master. The intervals with which scan activities can be carried out are discussed in Section 10.6.2 on page 96 and Section 10.7.2 on page 106.