Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Multiple clock support for VLC]
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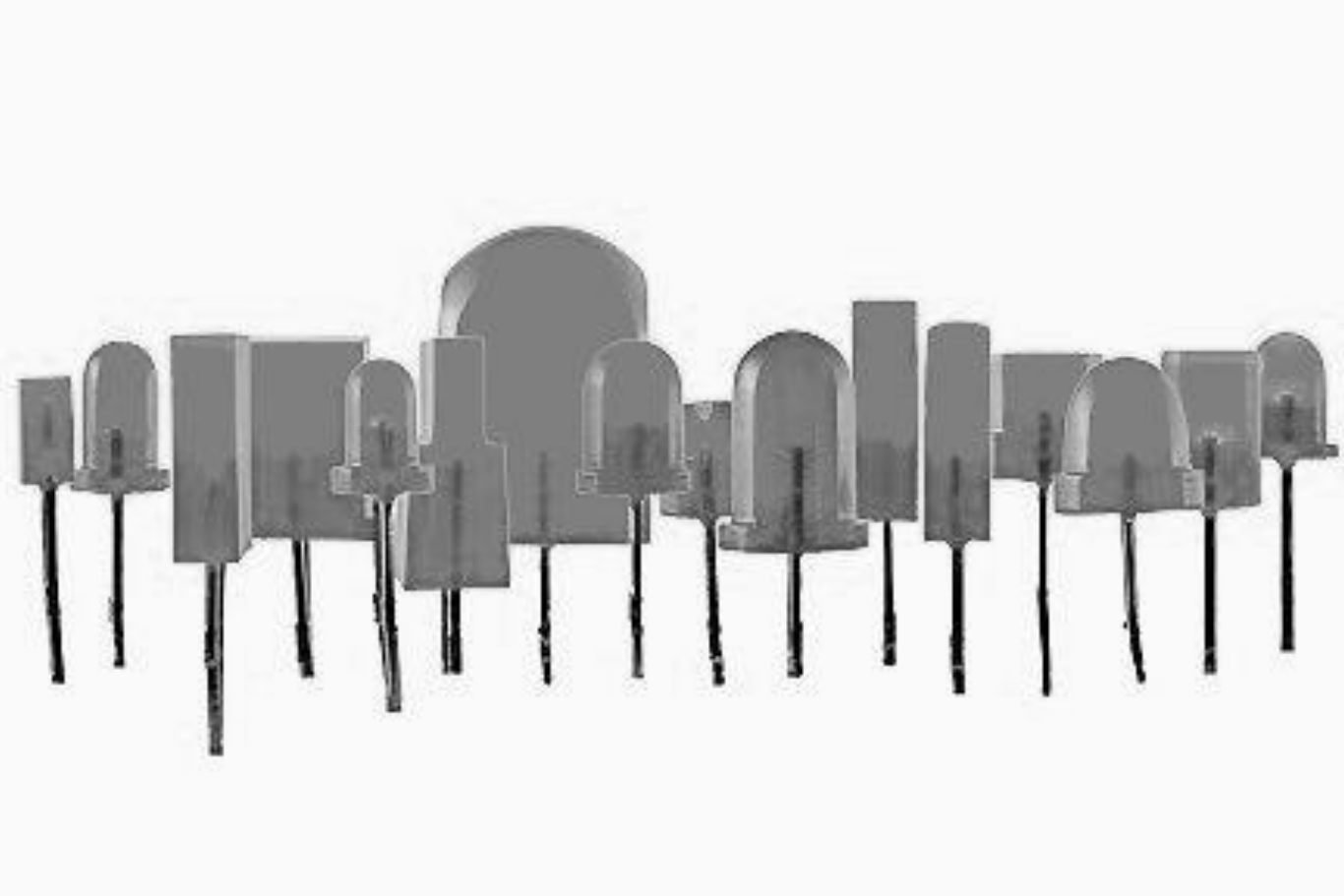
Re:

Abstract: Provides details on multiple clock support for VLC

Purpose: [Contribution to IEEE 802.15.7 VLC TG]

LED variety



LEDs come in various shapes, sizes and have varying bandwidth and switching frequencies from 100's of KHz to 100's of MHz

Need to support multiple clocks

Example: Illuminator or traffic light LED is different than a mobile phone LED and may have higher power but may have a lower switching frequency

Standard enables support for variety of applications, thereby supporting multiple clocks

Data rates – PHY I

	Optical rate	Modulation	Line coding	FEC	Data rate
PHY I	200 kHz	OOK	Manchester	1/16	6.25 kbps
	200 kHz	OOK	Manchester	1/8	12.5 kbps
	200 kHz	OOK	Manchester	1/4	25 kbps
	200 kHz	OOK	Manchester	1/2	50 kbps
	200 kHz	OOK	Manchester	1	100 kbps
	600 kHz	VPM	4B6B	1/2	200 kbps
	600 kHz	VPM	4B6B	1	400 kbps

Data rates – PHY II

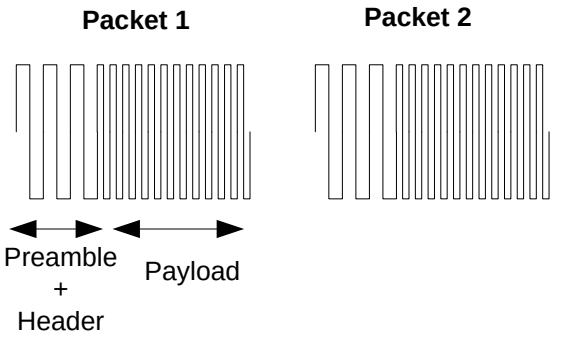
	Optical rate	Modulation	Line coding	FEC	Data rate
PHY II	6 MHz	VPM	4B6B	4/5	3.2 Mbps
	12 MHz	VPM	4B6B	4/5	6.4 Mbps
	24 MHz	OOK	8B10B	1/2	9.6 Mbps
	60 MHz	OOK	8B10B	1/2	24 Mbps
	60 MHz	OOK	8B10B	4/5	38.4 Mbps
	120 MHz	OOK	8B10B	4/5	76.8 Mbps
	120 MHz	OOK	8B10B	1	96 Mbps

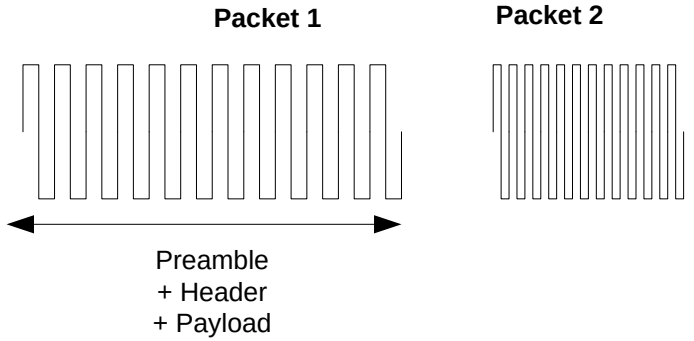
Options to support multiple clock frequencies

Options for supporting multiple clock frequencies

PHY layer
(support multiple clock frequencies within a packet)

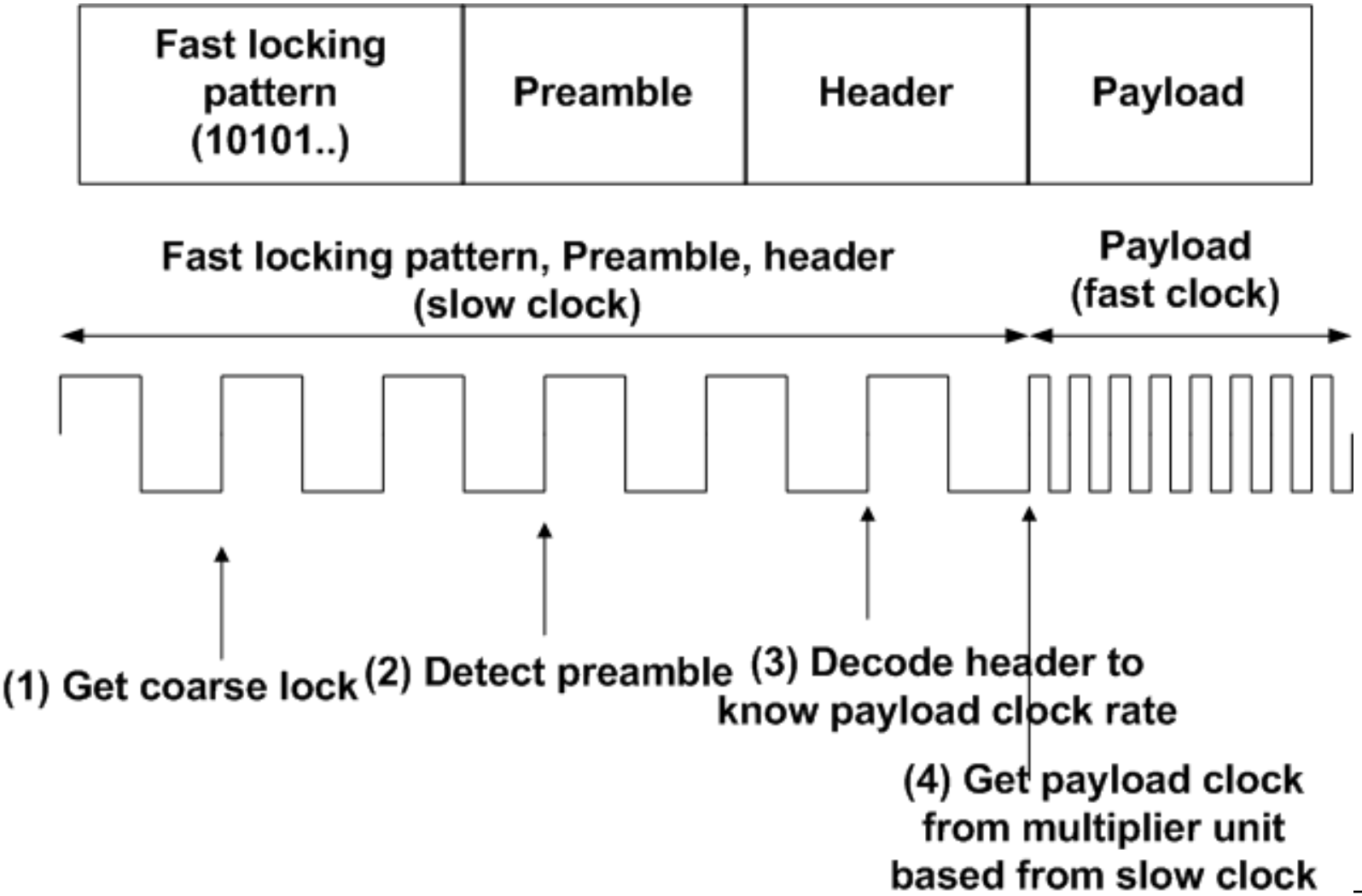
MAC layer
(support multiple clock frequencies across packets)



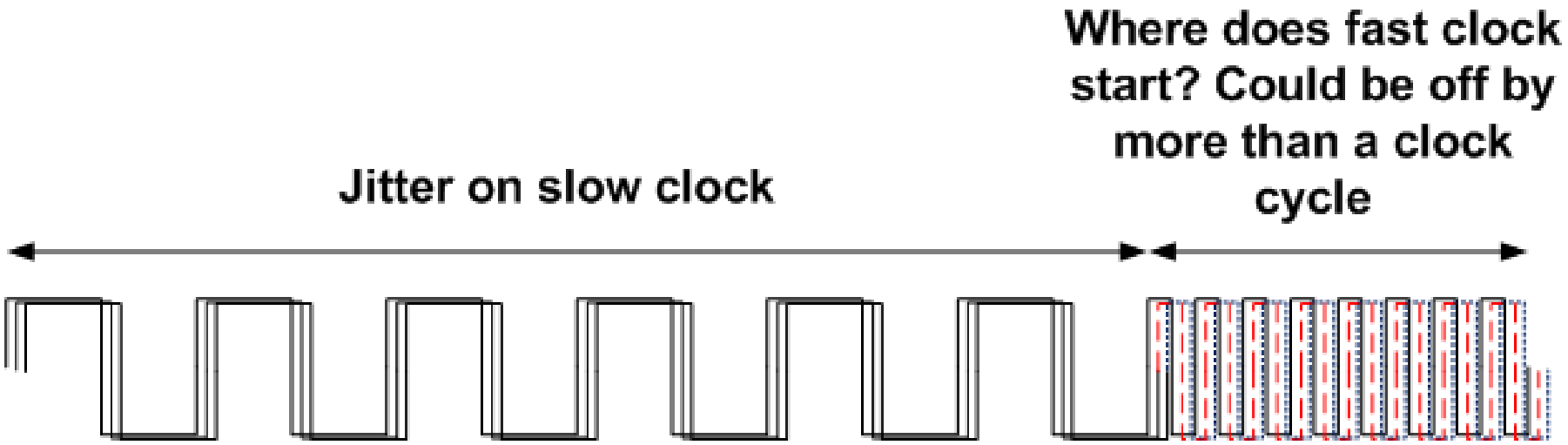


Option 1 : PHY support

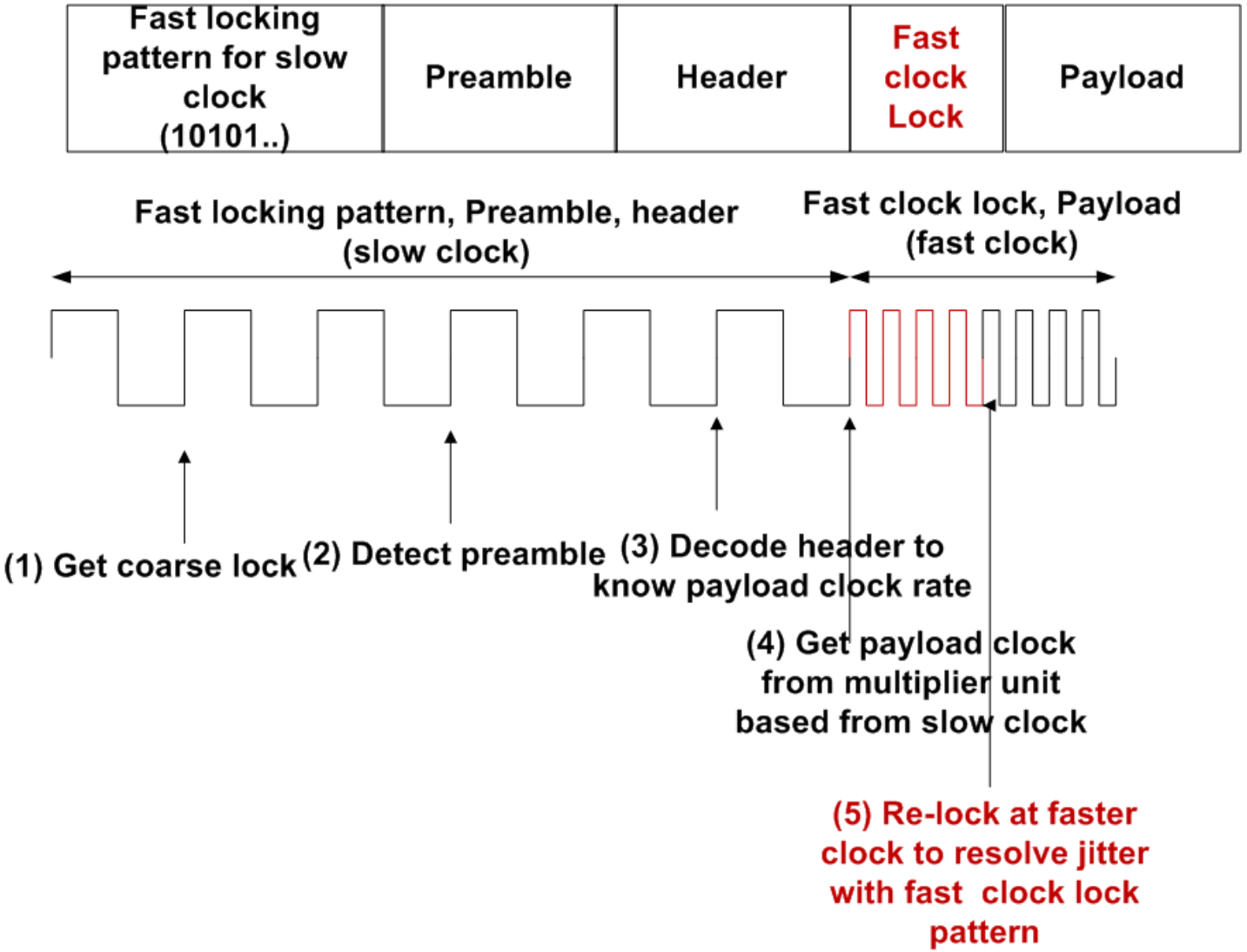
Current design



Jitter issue



One possible solution



Disadvantages of Option 1

Have to change clock in middle of PHY packet

- Sensitive to clock jitter
- Complex CDR
- Re-locking pattern

High data rate throughput reduced due to low clock rate for preamble and header – cannot have large data rate difference between lowest and highest rates

Option 2 : MAC support

Advantages

Used in typical standards. IrDA and RS-232 can select different clock speeds for P2P communications

We can support separation of clock rate range between the transmitter and the receiver. Transmitter and receiver are independent chains and may support different clock rate ranges.

- For example: a illuminator may be able to transmit only at 5 MHz due to its LED but it may be able to receive at 50 MHz due to its photodiode.

Illuminator can have high transmit power but low switching frequency. Mobile may have low transmit power but can use coding gain at higher switching frequency to communicate efficiently with the AP.

If all devices in network can support high speeds, after link establishment, there is no overhead due to slow clock as in PHY support

There is no forcing requirement to keep data rate range within an order of magnitude as if all devices can support higher clock speeds then lower clock speeds need not be used.

Sending packets at multiple clock rates

- Support for minimum clock rate for a given PHY type mandatory for TX and RX for all devices
- All specified clock rates less than the maximum supported clock rate in a given device will also be supported in that device.
- If a clock rate is supported, all data rates associated with that clock rate will be supported.
- Preamble, header and payload will have the same clock rate
- Header will be sent at lowest data rate for the chosen clock rate
- Payload can choose any data rate belonging to the chosen clock rate

2 options for clock change support

Some receivers may need to have explicit mention of new TX clock at the current (lowest) data rate before changing the TX clock to a new rate

Some receivers can derive knowledge of TX clock automatically during communication (as long as it is an integer multiple and it is less than the RX clock sampling frequency)

Example illustration

Support for lowest clock, for example, 6 MHz mandatory for TX and RX

Let device 1 be an access point. Let max TX clock Ct1 = 12 MHz, max RX clock Cr1 = 60 MHz. Let device 2 be a mobile. Ct1 = 60 MHz, Cr1 = 120 MHz.

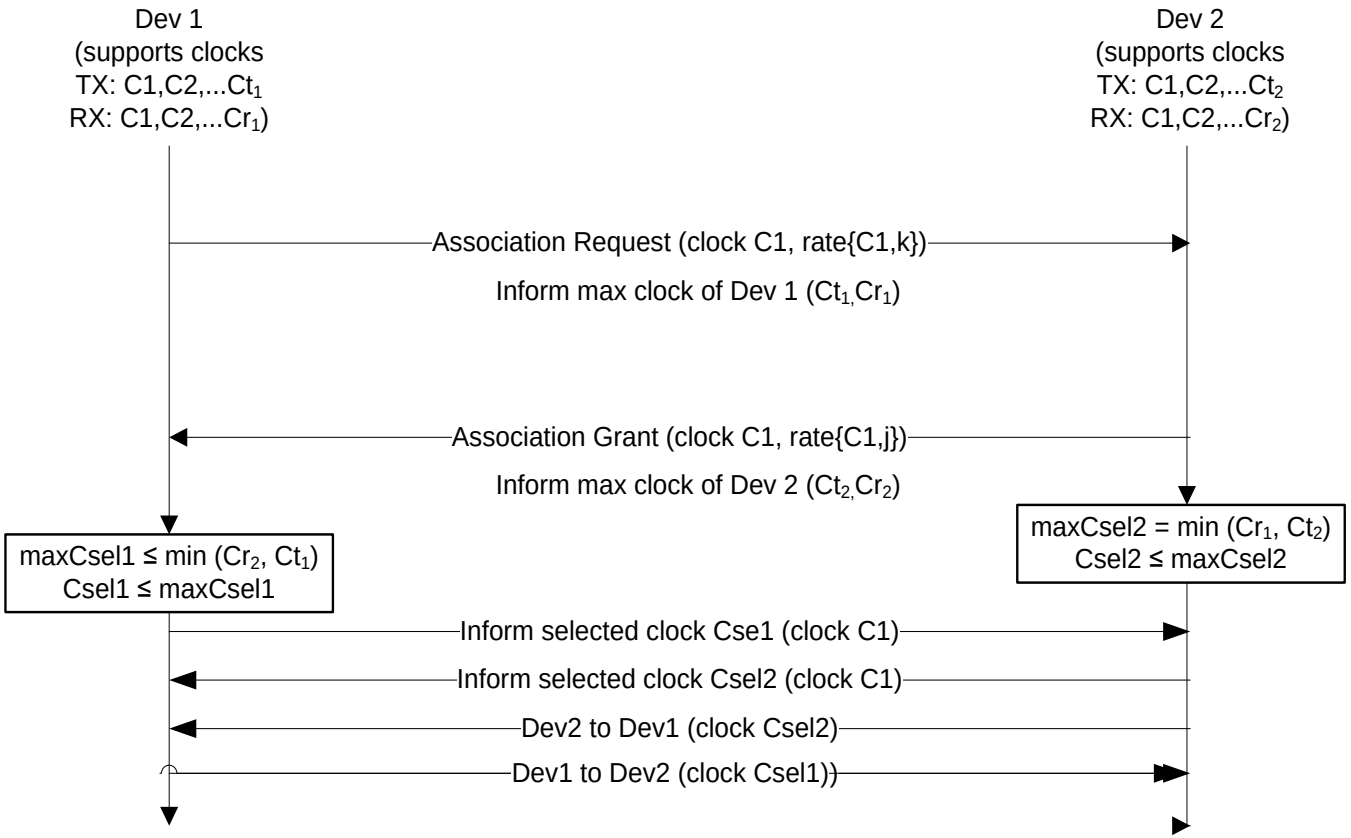
Establish link/associate at 6 MHz. Preamble, header, payload sent at 6 MHz.

After link establishment:

- Dev1 to Dev2 : <= 12 MHz. Preamble, header, payload sent at 12 MHz clock. PHY header sent at lowest data rate supported by 12 MHz.
- Dev2 to Dev1 : <= 60 MHz

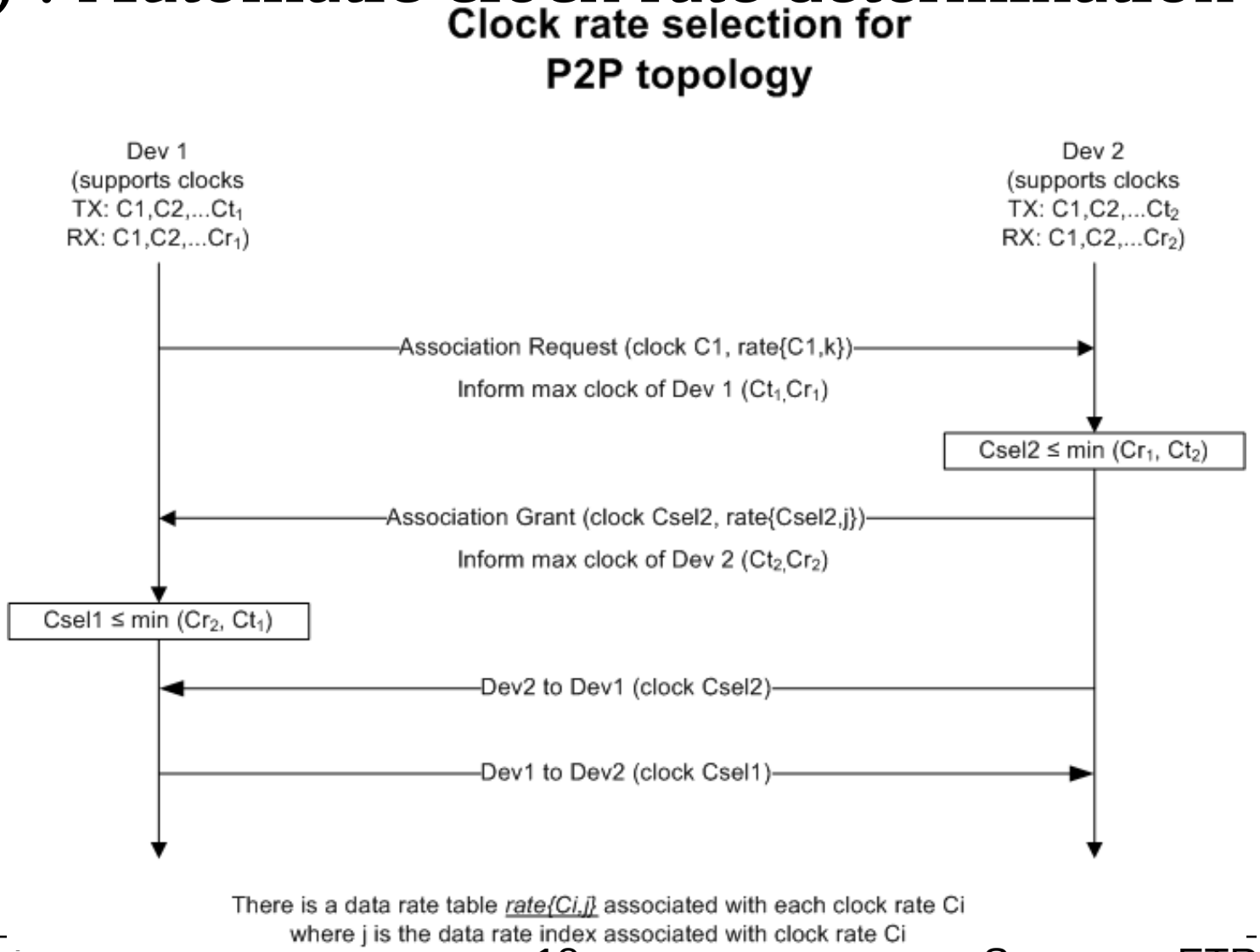
Option 2(a): Apriori information

Clock rate selection for P2P topology



There is a data rate table *rate{Ci,j}* associated with each clock rate Ci
where j is the data rate index associated with clock rate Ci

2(b) : Automatic clock rate determination



Receiver does not know ‘m’ in previous slide

Preamble pattern

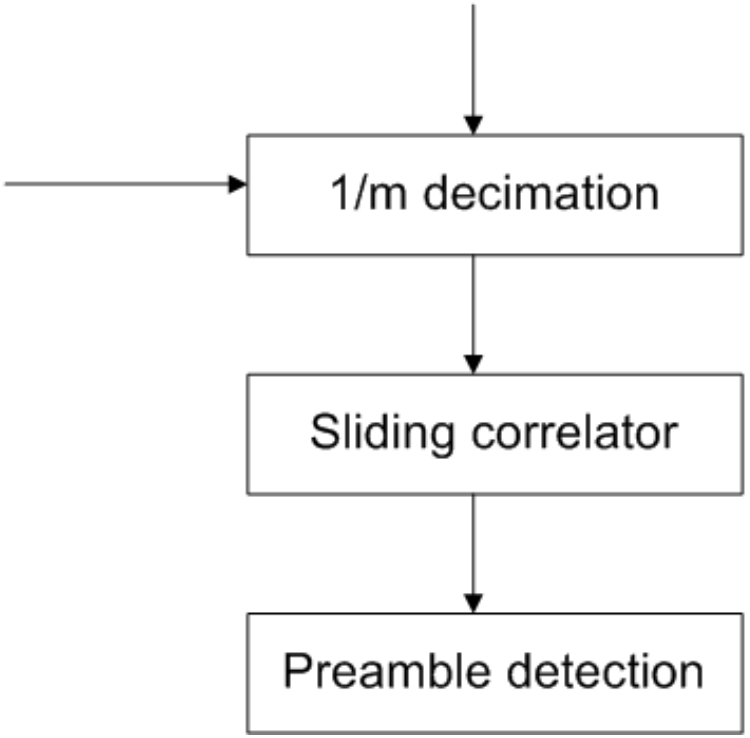
Transmitter clock C_t 1 0 1 0

Receiver clock C_r

$C_r/C_t = m \in Z$

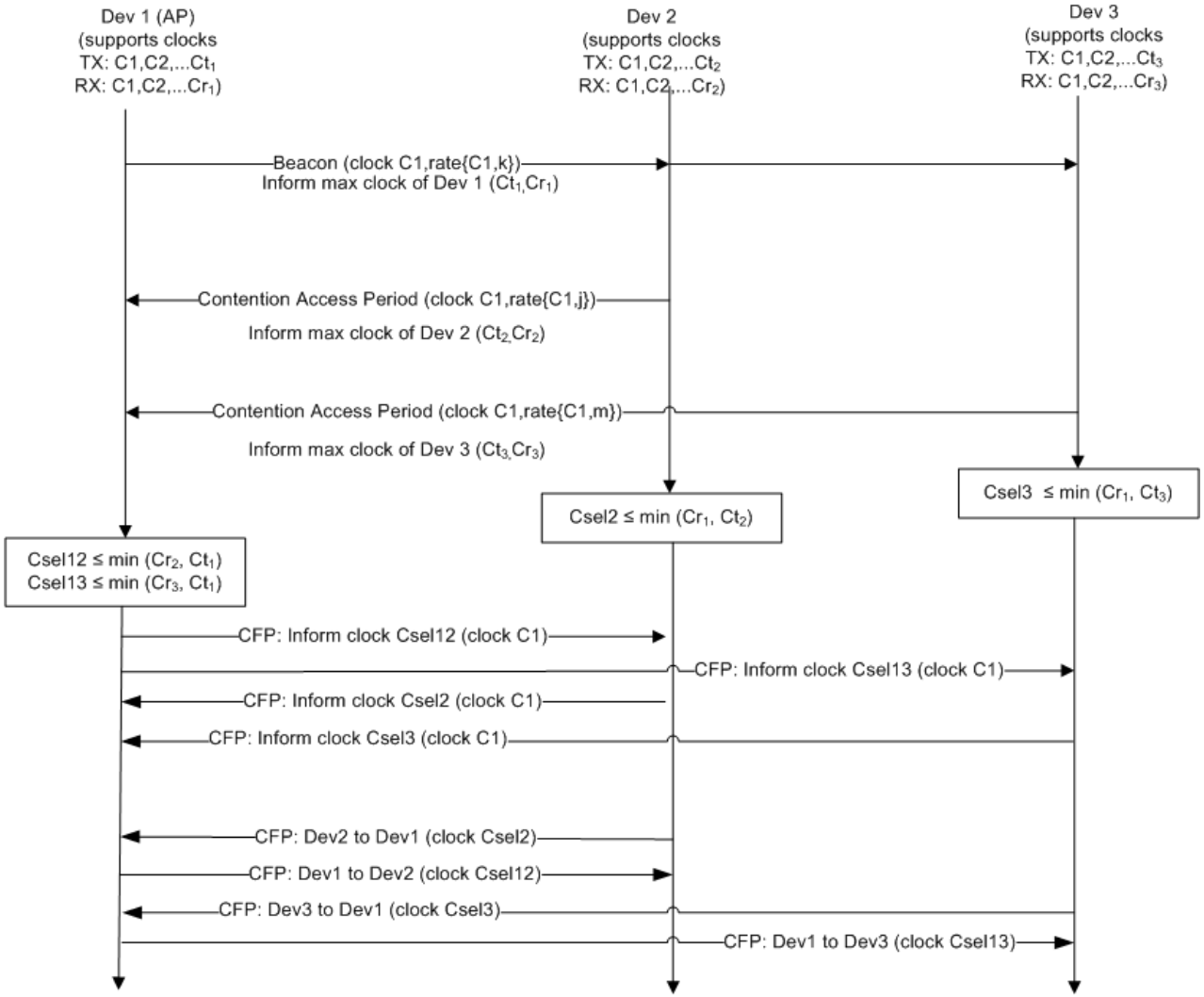
1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0

Rx can detect ‘m’ based on transitions
‘m’ can also be obtained via exhaustive search since ‘m’ has limited options



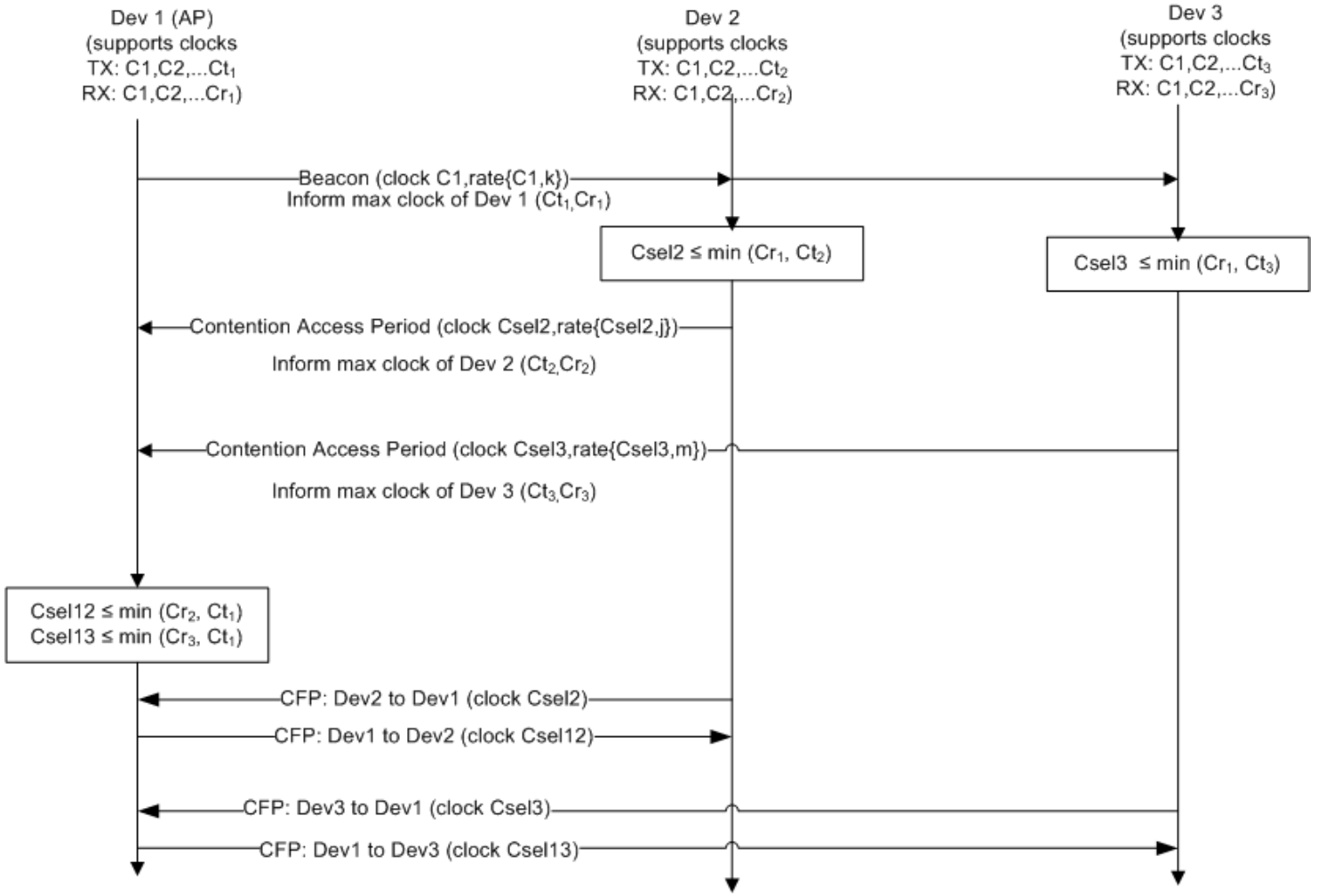
Option 2(a)

Clock rate selection for Star topology



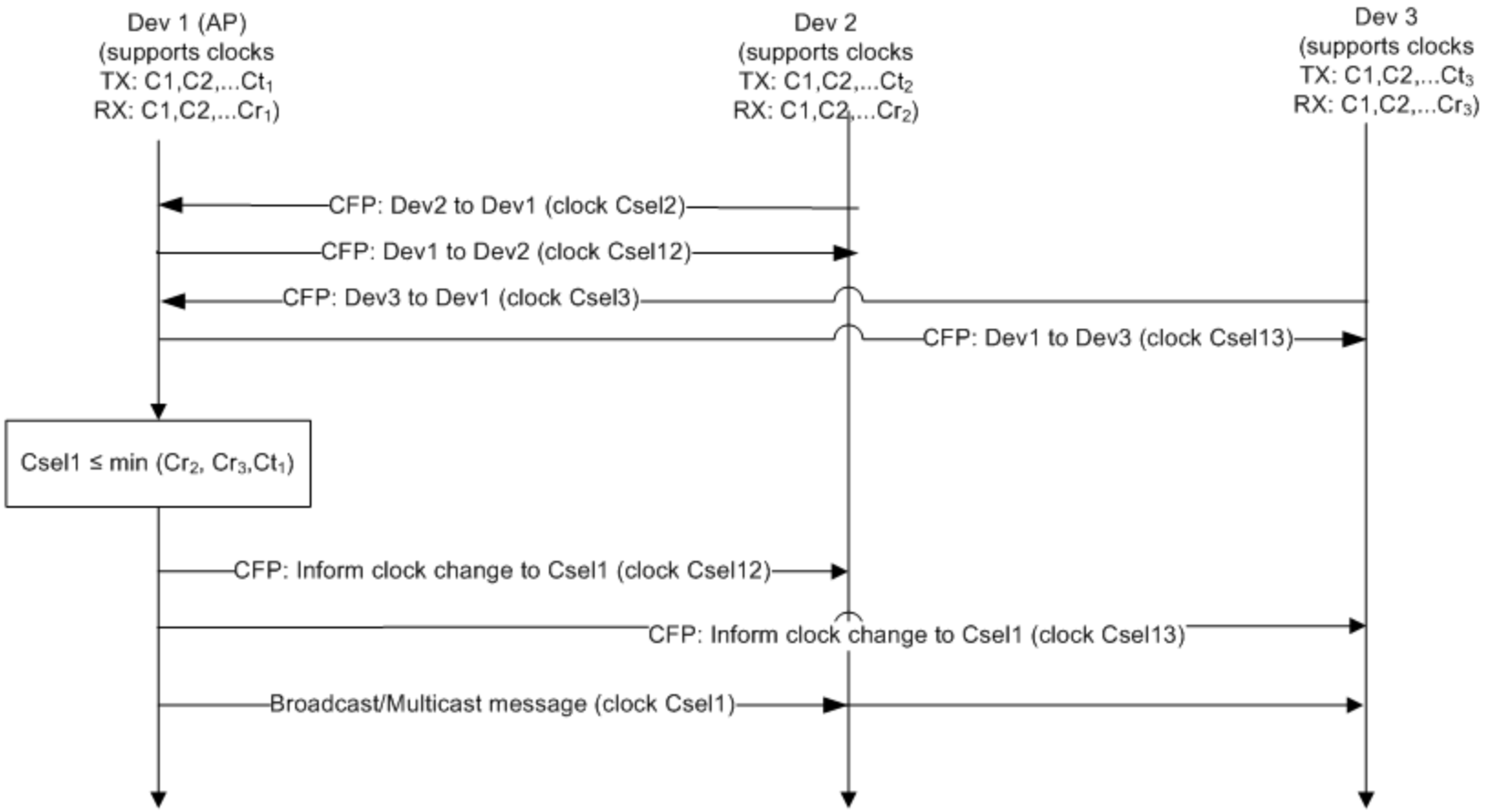
Option 2(b)

Clock rate selection for Star topology



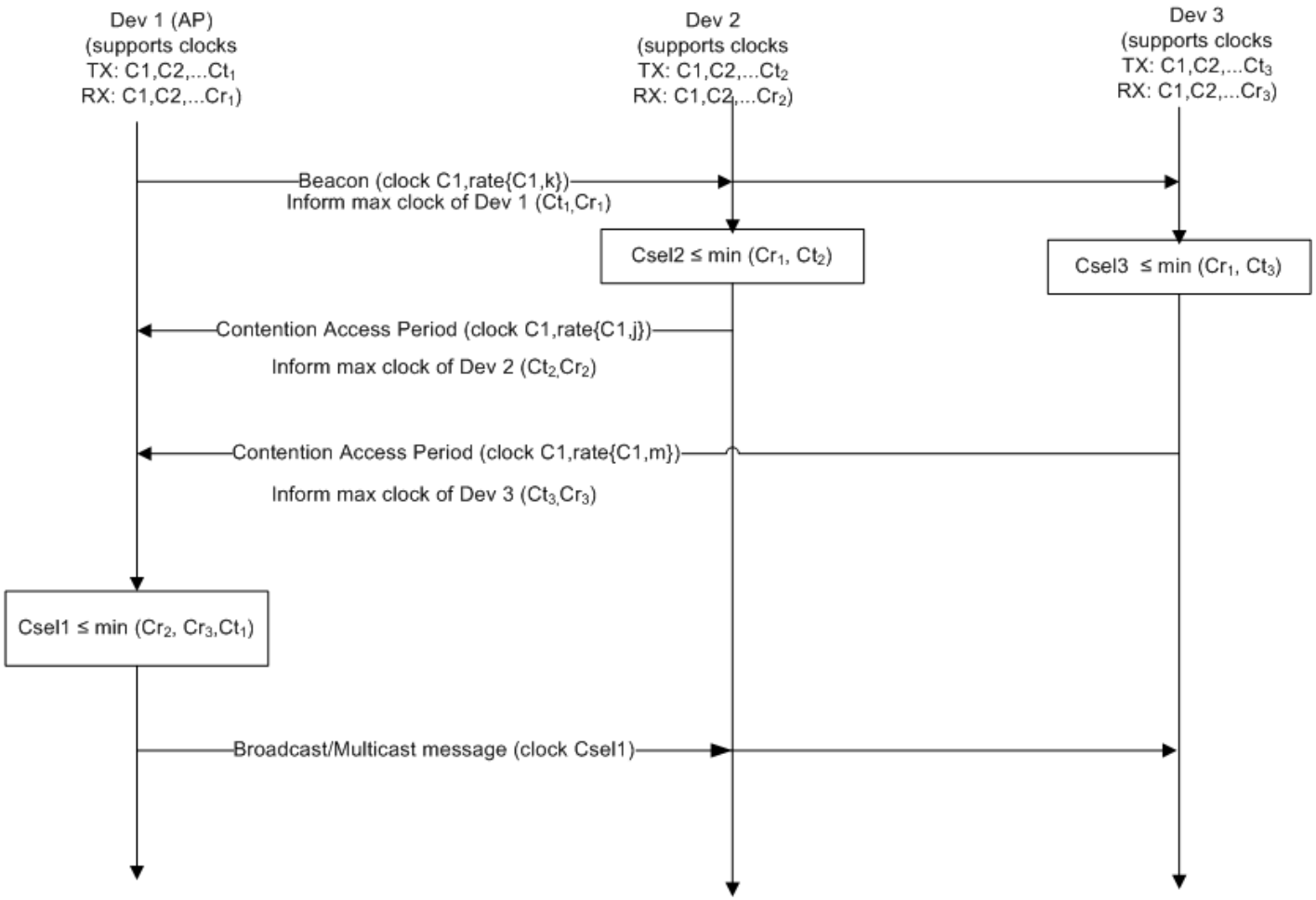
Option 2(a)

Clock rate selection for Broadcast/multicast topology



Option 2(b)

Clock rate selection for Broadcast/multicast topology



Changes to support proposed mechanisms

New rate tables (PHY I) – Clocks multiple of 2

	Optical rate	Modulation	Line coding	FEC	Data rate
PHY I	200 kHz	OOK	Manchester	1/16	6.25 kbps
				1/8	12.5 kbps
				1/4	25 kbps
				1/2	50 kbps
				1	100 kbps
	400 kHz	VPM	4B6B	1/8	33 kbps
				1/4	67 kbps
				1/2	133 kbps
				1	266.7 kbps

PHY II

	Modulation	Line coding	FEC	Optical rate	Data rate
PHY II	VPM	4B6B	1/2	3.75 MHz	1.25 Mbps
			4/5		2 Mbps
			1/2	7.5 MHz	2.5 Mbps
			4/5		4 Mbps
			1		5 Mbps
	OOK	8B10B	1/2	15 MHz	6 Mbps
			4/5		9.6 Mbps
			1/2	30 MHz	12 Mbps
			4/5		19.2 Mbps
			1/2	60 MHz	24 Mbps
			4/5		38.4 Mbps
			1/2	120 MHz	48 Mbps
			4/5		76.8 Mbps
			1		96 Mbps

MAC (or PHY) capability field

Bit	Attribute	Description
0	Traffic support	0 = unidirectional (broadcast only) 1 = bi-directional
1-2	Topology	00 = reserved 10 = P2P only 01 = P2MP support 11 = both
3-4	Device type	00 = infrastructure 01 = mobile 10 = vehicle 11 = reserved
5	Beacon capability	1 = capable
6	Visibility support	1= support
7	Dimming support	1 = support
8	Co-ordinator support	1 = support, can act as co-ordinator for VLAN
9-11	**Max supported TX clock**	**000 – lowest clock rate, 001 – next highest clock, …**
12-14	**Max supported RX clock**	**000 – lowest clock rate, 001 – next highest clock, …**
15	**Explicit clock notification request**	**1 = needs explicit clock notification at receiver**

Command frame notification

Command frame identifier	Command name
0x01	Association request
0x02	Association response
0x03	Disassociation notification
0x04	Data request
0x05	PAN ID conflict notification
0x06	Orphan notification
0x07	Beacon request
0x08	Coordinator realignment
0x09	GTS request
0x0a	Blinking notification
0x0b	Dimming notification
0x0c	Fast link recovery signaling
0x0d	Mobility notification
0x0e	Information element exchange
0x0f	**Clock rate change notification**
0x10–0xff	Reserved

Clock rate change notification command format

octets:	1	1
MAC Header fields	Command Frame Identifier	New clock rate for future TX