

Ultra Low Power Wi-Fi
for embedded Applications



Is Better

Getting Connected with Wi-Fi

GainSpan[®]

June 2010

GainSpan “b” is a Better Choice For Connecting Things

❑ Connecting Things to the Internet

- Sending small amounts of data/commands, intermittently
- Off/sleeping a lot (most of the time)
- Range is an important consideration, in order to provide flexibility in the location of the “thing” relative to the access point
- Power and dynamic power management are essential for battery powered “things”
- “Things” have low speed host connections – UART, SPI



❑ 802.11b

- Compatible/interoperable with 802.11b/g/n networks
- Provides wireless connectivity rates from 1-11Mb/s
- Provides better sensitivity and range (DSSS & BPSK) at 1Mb/s than 802.11g/n
- More Tx power efficient (Peak to Average signal ratio)

802.11	Modulation	PAR
b	DSSS	2dB
g/n	OFDM	6dB



“b is better for Tx power efficiency”

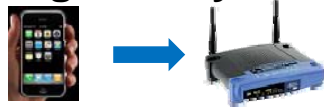
(Source: “Power Measurements of OFDM Signals” Elliott Laboratories, Sunnyvale CA)

- Provides more than enough bandwidth for “Things”
- GainSpan has incorporated Clear to Send-to-Self and short slot times in the GS1011

802.11b/g/n Signal Processing Comparison



❑ Performance is generally limited by “up” link



- Output power is for the “Thing” (Client)
- Receiver sensitivity is for the access point

❑ DSS/BPSK has a lower TX peak to average ratio than OFDM/64-QAM

- Less PA back off, and more resulting client transmit power for 802.11b

❑ BPSK provides less throughput but more Rx sensitivity

- Better sensitivity means more distance/range
- Capacity

Modulation	bits/sec/Hz
BPSK	1
64-QAM	6

802.11	Data Rate (Mbps)	Modulation	Modulation Scheme	Output Power (dBm)	Receiver Sensitivity (dBm)	Net Link Budget (dB)
b	1	DSSS	BPSK	18	-94	112
b	2	DSSS	QPSK	18	-91	109
b	5.5	DSSS	CCK	18	-87	105
g	6	OFDM	BPSK	15	-87	102
n	7.2	OFDM	BPSK	13	-86	99
g	9	OFDM	BPSK	15	-86	101
b	11	DSSS	CCK	18	-85	103
g	12	OFDM	QPSK	15	-83	98
n	14.4	OFDM	QPSK	13	-85	98
g	18	OFDM	QPSK	15	-82	97
n	21.7	OFDM	QPSK	13	-84	97
g	24	OFDM	16-QAM	15	-81	96
n	28.9	OFDM	16-QAM	13	-83	96
g	36	OFDM	16-QAM	15	-80	95
n	43.3	OFDM	16-QAM	13	-80	93
g	48	OFDM	64-QAM	15	-75	90
g	54	OFDM	64-QAM	15	-74	89
n	57.8	OFDM	64-QAM	13	-75	88
n	65	OFDM	64-QAM	13	-74	87
n	72.2	OFDM	64-QAM	13	-73	86

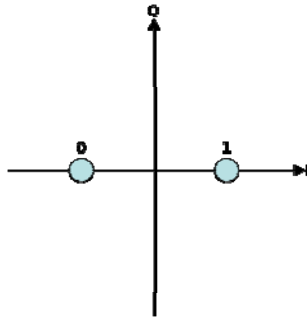
802.11n 802.11g 802.11b

(Typical, industry values)

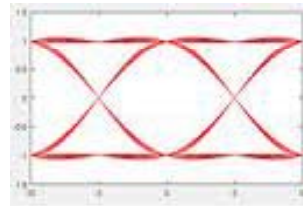
802.11b/g/n Sensitivity

Constellations

BPSK

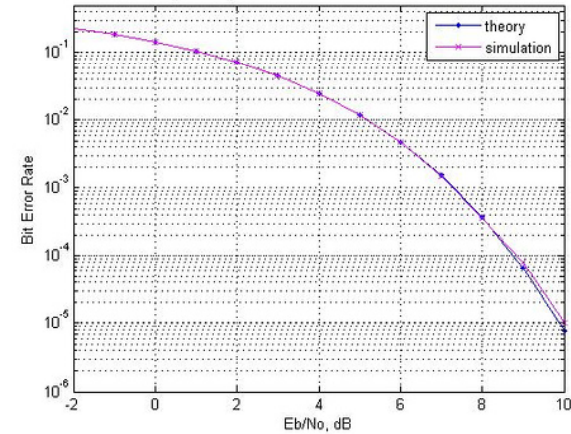


Eye Diagrams

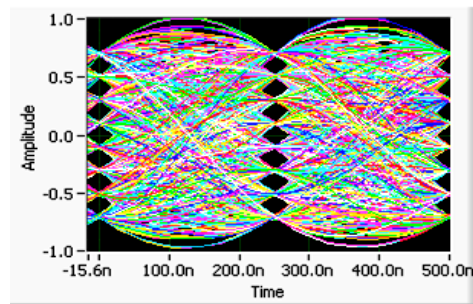
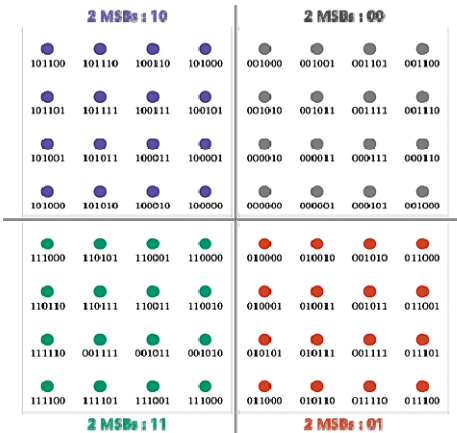


Error Probability

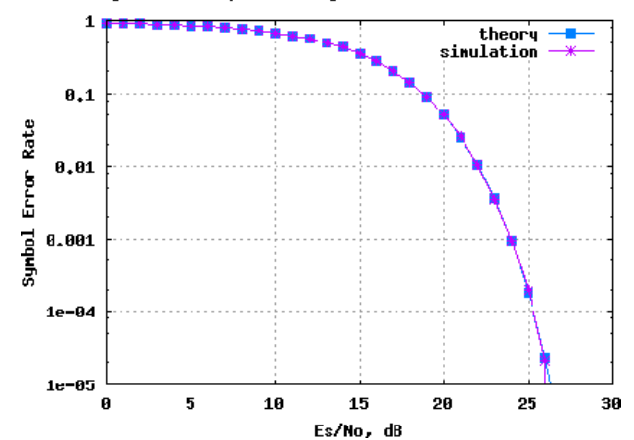
Bit error probability curve for coherent demodulation of DBPSK



64 QAM



Symbol error probability curve for 64-QAM modulation



(17dB difference at 10^{-3} error rate)

- ❑ 802.11b 1 Mb/s (BPSK) has the best Rx sensitivity
- ❑ 802.11b 1 Mb/s (DSS) is the most robust with multi-paths

802.11b/g/n Link Budget Comparisons

Mode	Minimum Data rate	Link budget (dBm)	FSL Distance (km)	Distance Ratio	FSL Area (sq.Km)	Area Ratio
802.11b	1 Mb/s	112	3.88	4.6	47	20.8
802.11g	6 Mb/s	102	1.22	1.4	5	2.1
802.11n	7.2 Mb/s	99	0.85	1.0	2	1.0

- ❑ 802.11 link budgets vary due to client Tx power and access point Rx sensitivity
- ❑ Distance is a function of link budget and signal loss/attenuation

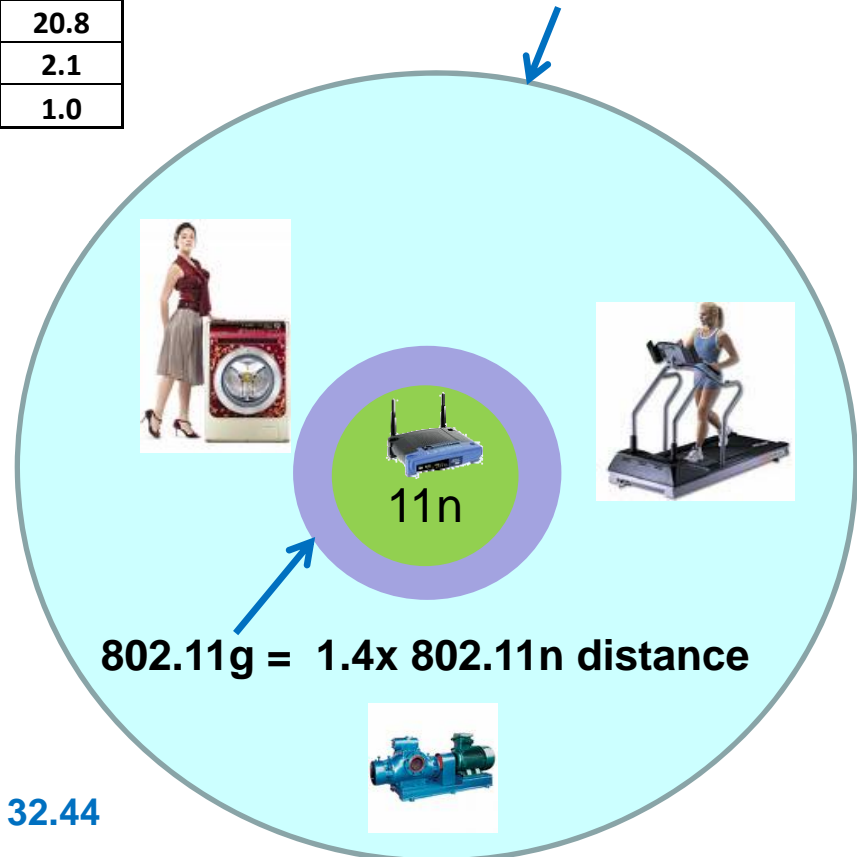


"b is better for distance"

$$FSPL (dB) = 20 \log_{10} (d) + 20 \log_{10} (freq) + 32.44$$

(d in meters, f in MHz)

802.11b = 3.3x 802.11g distance



802.11g = 1.4x 802.11n distance

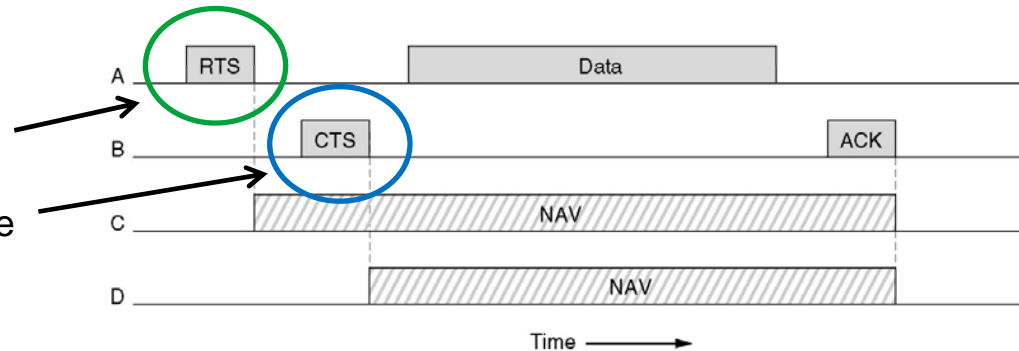
Minimum data rate, free space

Minimizing the Impact of 802.11 b & g Mixed Networks

❑ 802.11 protection mechanism

Request to Send can be sent at g rates

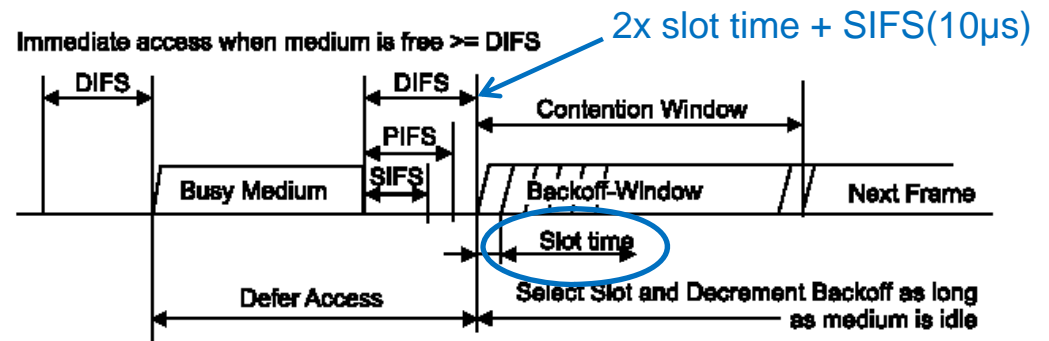
Clear to Send must be sent at b rates in a mixed network



❑ GS1011 implements a CTS-to-self to eliminate the overhead of a full RTS/CTS cycle

❑ GS1011 implements short slot times to reduce time between frames/busy medium

Devices	Slot Time
Other 802.11b	20µs
802.11g	9µs
GS1011 802.11b	9µs

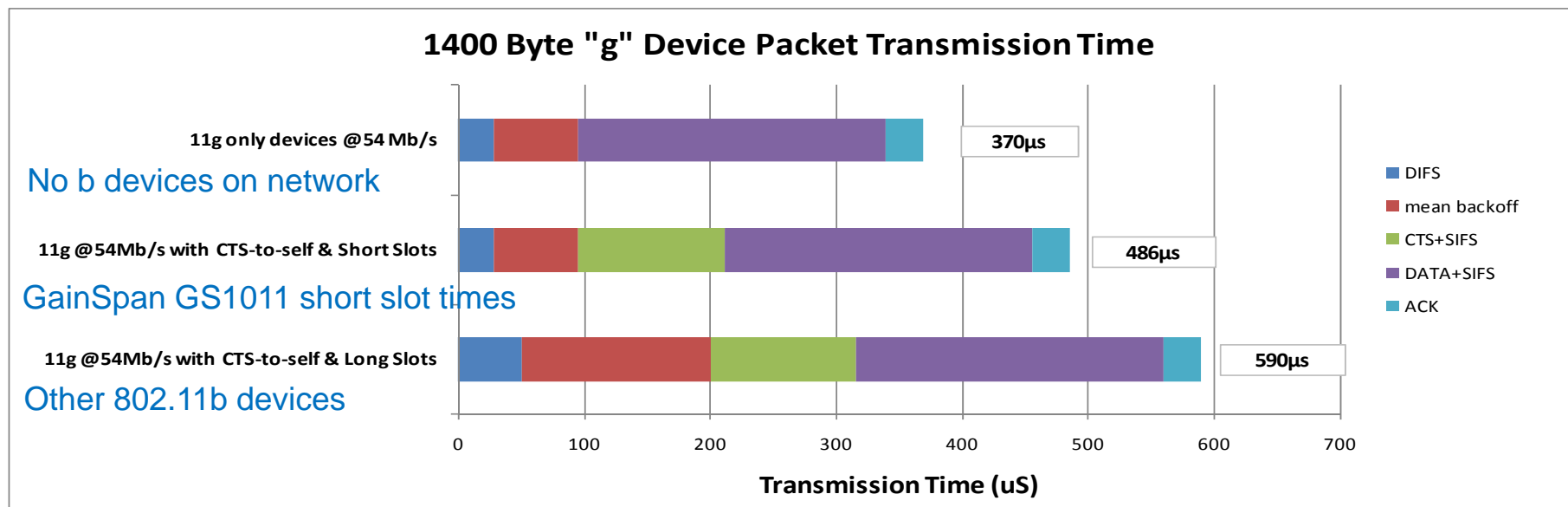


"GainSpan b is better"

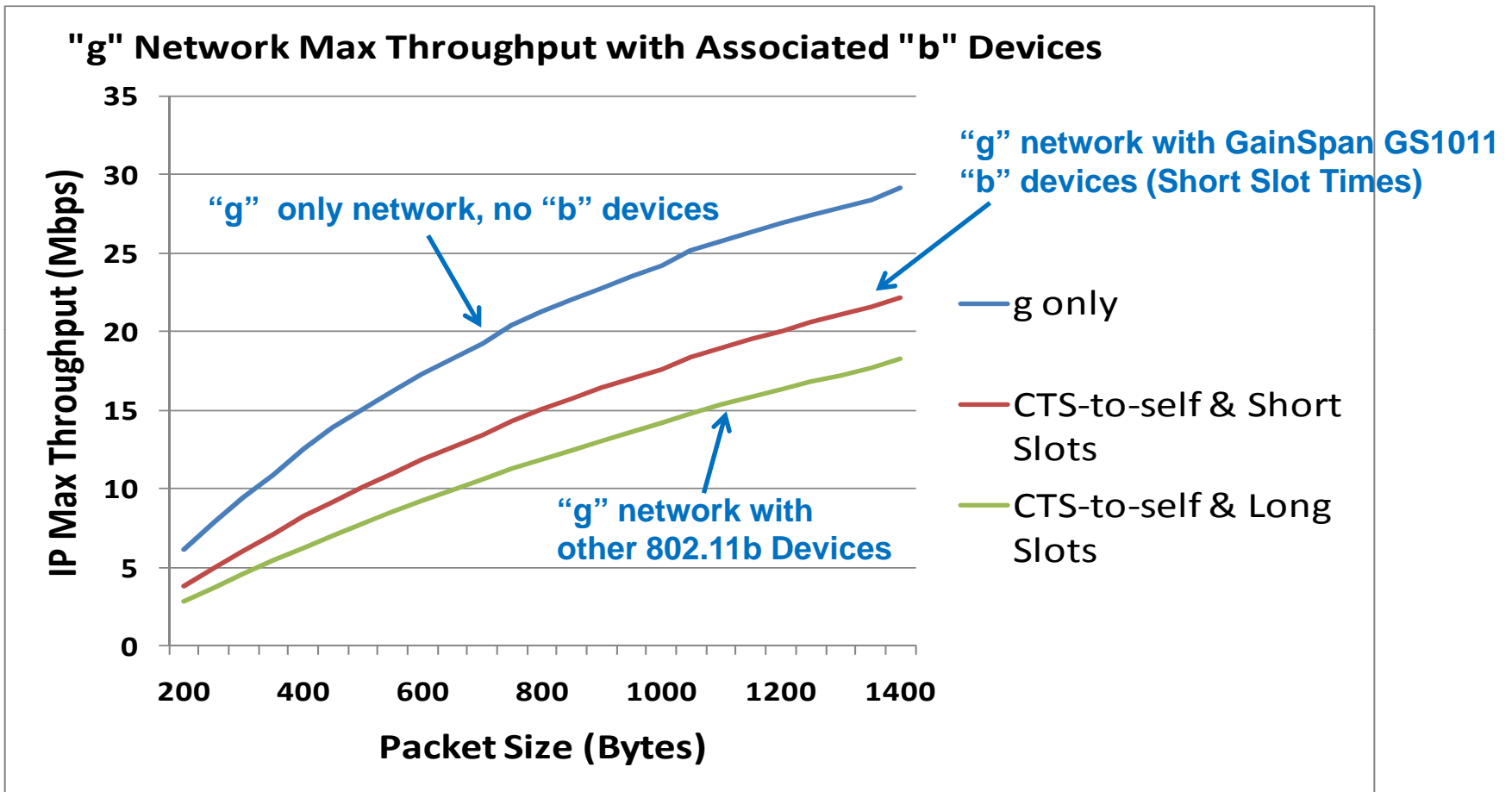
GainSpan

Mixed 802.11b/g Compared With 802.11g Only Networks

- ❑ “g” devices operate at “g” rates and “b” devices operate at “b” rates in a mixed network
 - The whole network does not run a “b” rates
- ❑ Summary of protection mechanism
 - “g” APs turn on CTS-to-self (uses b rates) when b clients are detected
 - Protection can only disabled if no b clients are in vicinity
- ❑ GS1011 implements the short (9μs) slot times of a “g” network



802.11g Max Throughput/Capacity



Source: http://www.veriwave.com/pdf/07/VeriWave_80211_capacity_Calculator.xls

Summary of Mixed 802.11b/g Networks

- ❑ **802.11b is a good choice for connecting “Things” to the internet**
 - Range from access point
 - Transmit power efficiency
 - Lower power
 - Connection rates up to 11 Mb/s
- ❑ **“b” devices require “g” networks to enable a CTS-to-Self protection feature to allow a mixed network**
 - Reduces a “g” only network maximum throughput/capacity
 - “g” devices continue to connect at “g” rates in a mixed network
- ❑ **GainSpan’s GS1011 802.11b solution is designed to minimize the impact overall network performance**
 - Short Slot Time
 - Ability to rapidly reboot and re-associate to AP with minimal network performance change (runs as a “pure g” network while disassociated)

