TFI Wireless Forecast

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Wireless Universe?

- Wireline – Places
- Wireless Voice – People
- Wireless Data – Devices
- Wireless Potential – All things fixed or mobile, man or machine (Now referred to as the Internet of Things)
- We now separately forecast standard connections and M2M connections

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M2M Connections Vs Standard Connections

- Most M2M requires much less bandwidth.
- M2M often needs different geographic coverage.
- M2M needs low cost, low power solutions.
- Time of day usage patterns are different.
- LTE categories 1 and 0 will address these issues.

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Forecast of Standard Connections

- The forecast of standard connections is based on the Gompertz Model (appropriate for primarily consumer adoptions) fitted to historical data from the CTIA dating to 1984.

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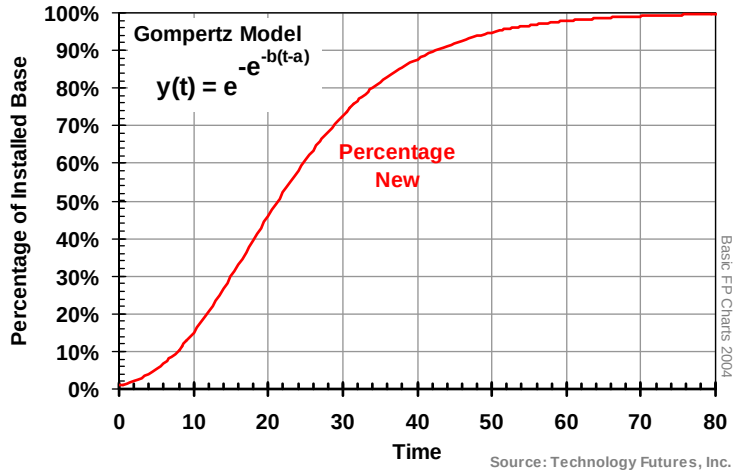
The Gompertz Model



y(t) = Fraction of market taken over by new technology at time "t"
"a" is 37% time; "b" determines rate of substitution

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The Internet of Things includes many items that won't likely be connected to cellular network

- The IoT is projected to be many billions. The items can be grouped by those that will have tags and those that will have connections (M2M). Projections for mobile M2M connections are less than 10% of IoT total.
- The GSMA estimates 20% of M2M will connect to the cellular network.
- TFI forecast is for US M2M cellular connections.

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Forecast of M2M Connections

- For M2M connections, we use the Fisher Pry Model (more appropriate for business-driven adoptions) and a growth rate "r value" of 25%, consistent with the current trajectory and most conservative projection of a February 2015 GSMA paper on the growth rates of M2M.
- Historical data points are primarily from same report and TFI estimates based on combined GSMA and CTIA data. For YE 2015 the estimation is 60.5M

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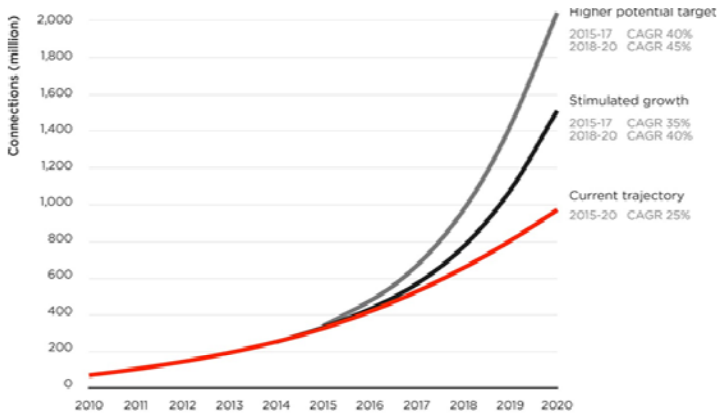
Global M2M Growth Rates



Source: GSMA 2015

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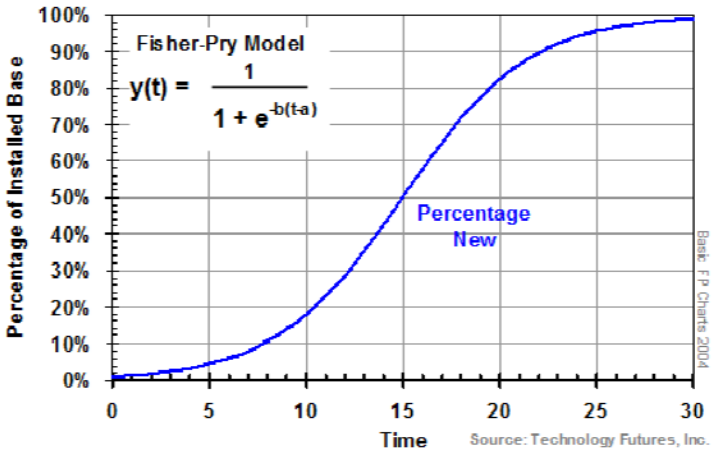
The Fisher-Pry Model



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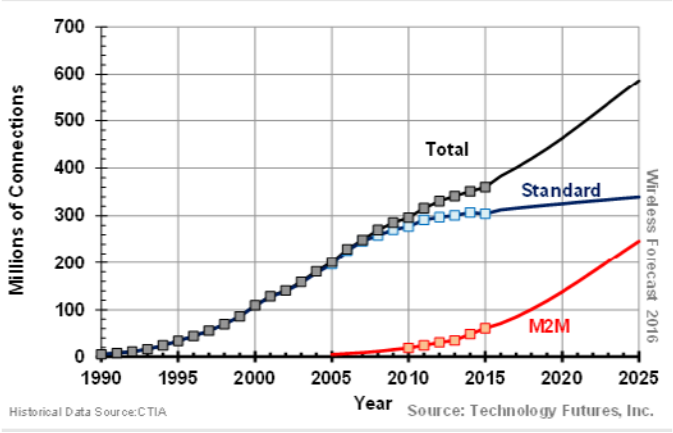
2016 TFI Wireless Connection Forecast



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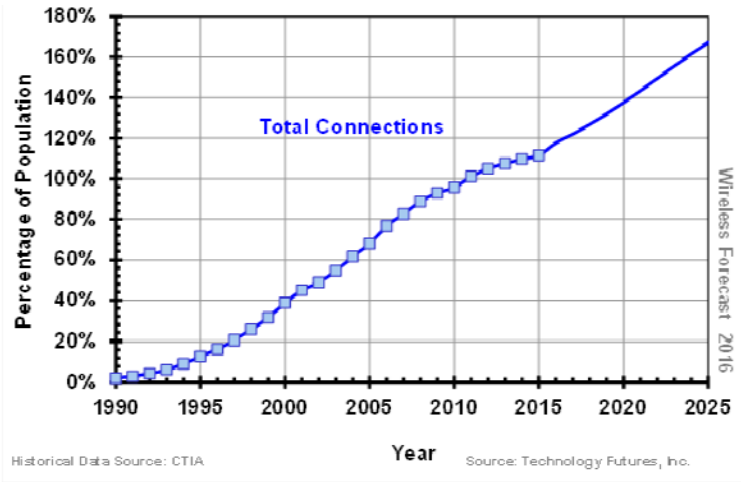
U.S. Cellular Connections, Percentage of Population



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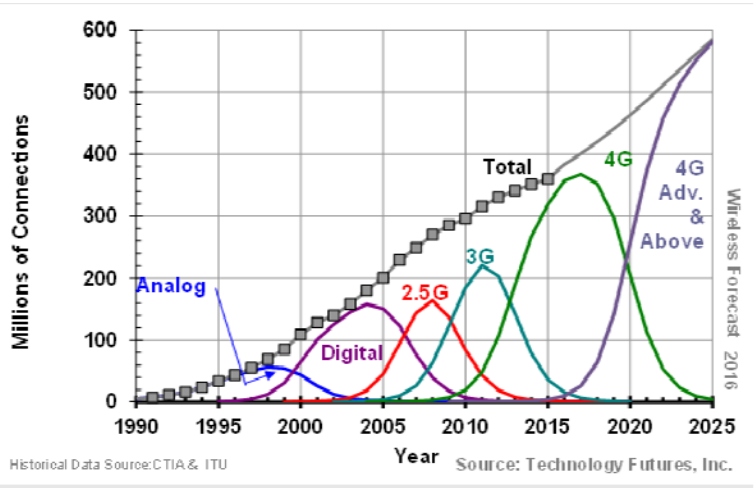
2016 TFI Wireless Generations Forecast



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Two Key Drivers for New Generations

- Mobile data traffic is growing much more rapidly than connections
- Greatly improving cost/performance of newer technology

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Technology Performance Improvement

- Technology performance for cellular technology is typically measured by system spectral efficiency which is defined here as Mbps/MHz/Site. This has improved very considerably over generations of equipment.

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Efficiency of Wireless Technology Generations

Spectral Efficiency of Cellular Wireless Systems

US 1% P Year	Gen	Standard	Max Net Bitrate/ carrier/ Sp stream (Mbps)	Bandwidth Per Carrier (MHz)	Max Link Efficiency (Mbps/MHz) SISO	MIMO	Typical Reuse	System Efficiency (Mbps/MHz/Site)
1983	1G	AMPS	0.0008	0.03	0.01		1/7	0.001
1991	2G	D-AMPS	.013 x 3 TS = .039	0.03	1.3		1/3	0.144
2000	2G	GSM	.013 x 8 TS = .104	0.2	0.65		1/3	0.173
2000	2G	CDMA 2000	22 calls	1.2288	.0179/call		1	0.179
	2G	Average						0.163
2002	2.5G	GSM+EDGE	.384 (.2 typ.)	0.2	1.92 (1 typ)		1/3	0.33
2002	2.5G	CDMA 1x RD	0.153	1.2288	0.125		1	0.179
	2.5G	Average						0.251
2003	3G	CDMA EV-DO	3.072	1.2288	2.5		1	1.3
2006	3G	UMTS	0.384	5	0.077			0.04
	3G	Average						0.905
2007	3.5G	HSDPA	21.1	5	4.22		1	4.22
2008	4G	LTE	81.6	20	4.08	16/32	1	16.32
2012	4G	LTE Adv	?3	20	3.75	30	1	30

Source: Technology Futures, Inc.

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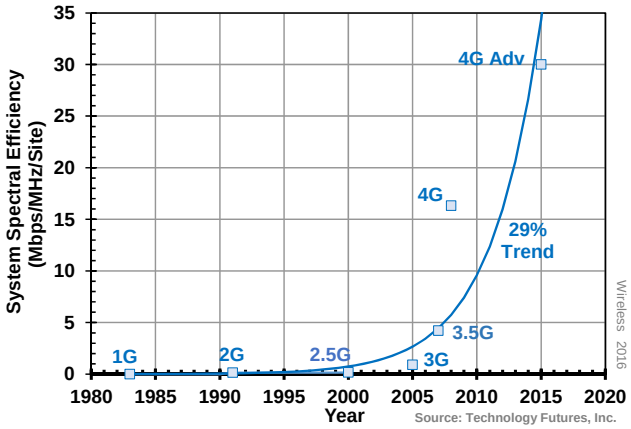
Performance Improvements of Cellular Wireless Generations



Source: Technology Futures, Inc.

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