

Exhibit 1018

IEEE 802.11n WLAN Standard

IEEE 802.11n Wi-Fi standard adopted technologies including OFDM and MIMO to enable it to provide high speed data at 600 Mbps peak for wireless LANs & wireless communications.

WiFi IEEE 802.11 Types Includes:

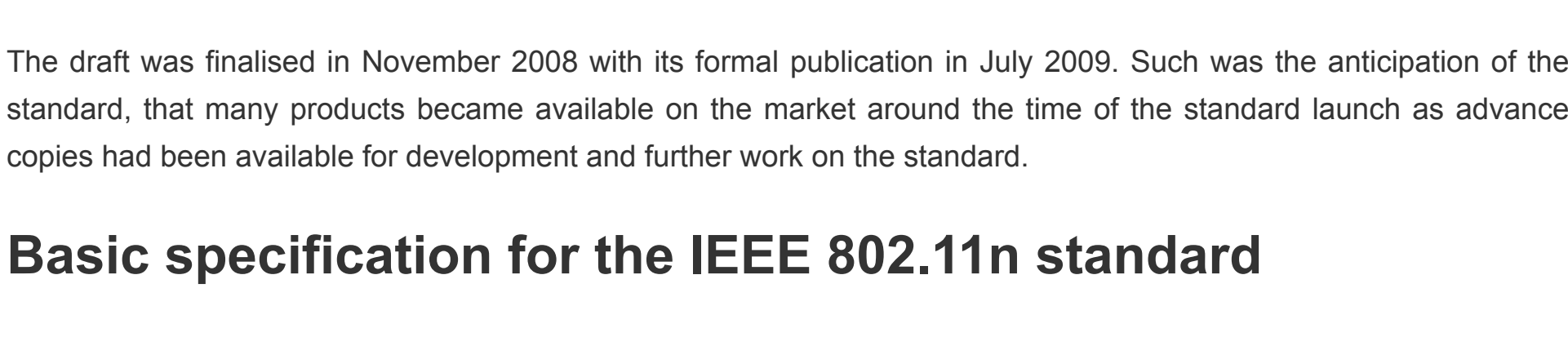
Standards 802.11a 802.11b 802.11g 802.11n 802.11ac 802.11ad WiGig 802.11af White-Fi 802.11ah Sub GHz Wi-Fi 802.11ax Wi-Fi 6 802.11be Wi-Fi 7

802.11 topics: Wi-Fi IEEE 802.11 basics Standards Wi-Fi Alliance generations Security Wi-Fi Bands Router location & coverage How to buy the best Wi-Fi router

IEEE 802.11n was the next of the IEEE 802.11 series of wireless LAN standards after 802.11a, 802.11b, and 802.11g to enable the higher performance. The major innovations are summarised below:

IEE 802.11n WLAN standard sought to increase the achievable speeds of Wi-Fi networks beyond that achievable using 802.11g. With increased levels of high data being transferred, often driven by the use of video, the IEEE sought to keep a step ahead of requirements and ensure that Wi-Fi was able to meet the needs of users for the coming years.

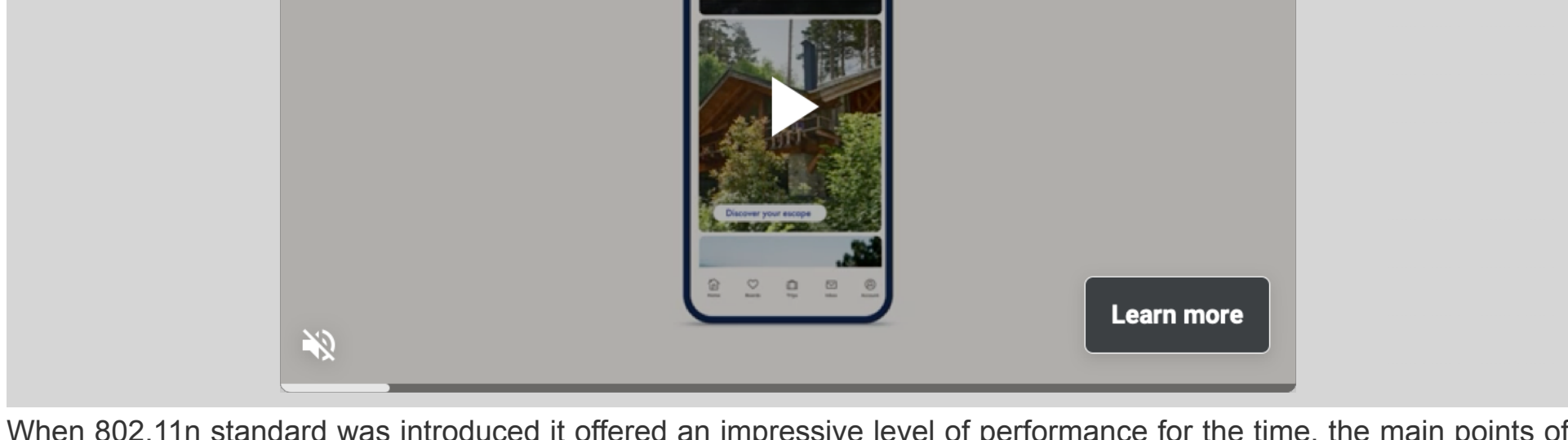
The industry came to a substantive agreement about the features for the 802.11n wireless LAN system in early 2006. This gave many chip manufacturers sufficient information to get their developments under way.



Basic specification for the IEEE 802.11n standard

The idea behind the IEEE 802.11n standard was that it would be able to provide much better Wi-Fi performance and be able to keep pace with the rapidly growing speeds provided by technologies such as Ethernet.

With a growing reliance on Wi-Fi and wirelesslocal area network technology in general it was necessary to ensure that the standards moved forward to ensure that they provided the required level of service.



When 802.11n standard was introduced it offered an impressive level of performance for the time, the main points of which are summarised below:

IEEE 802.11N WIRELESS LAN SALIENT FEATURES	
PARAMETER	IEEE 802.11N STANDARD
Maximum data rate (Mbps)	600
RF Band (GHz)	2.4 or 5
Modulation	CKK, DSSS, or OFDM
Number of spatial streams	1, 2, 3, or 4
Channel width (MHz)	20, or 40

To achieve this a number of new features that have been incorporated into the IEEE 802.11n wireless LAN standard to enable the higher performance. The major innovations are summarised below:

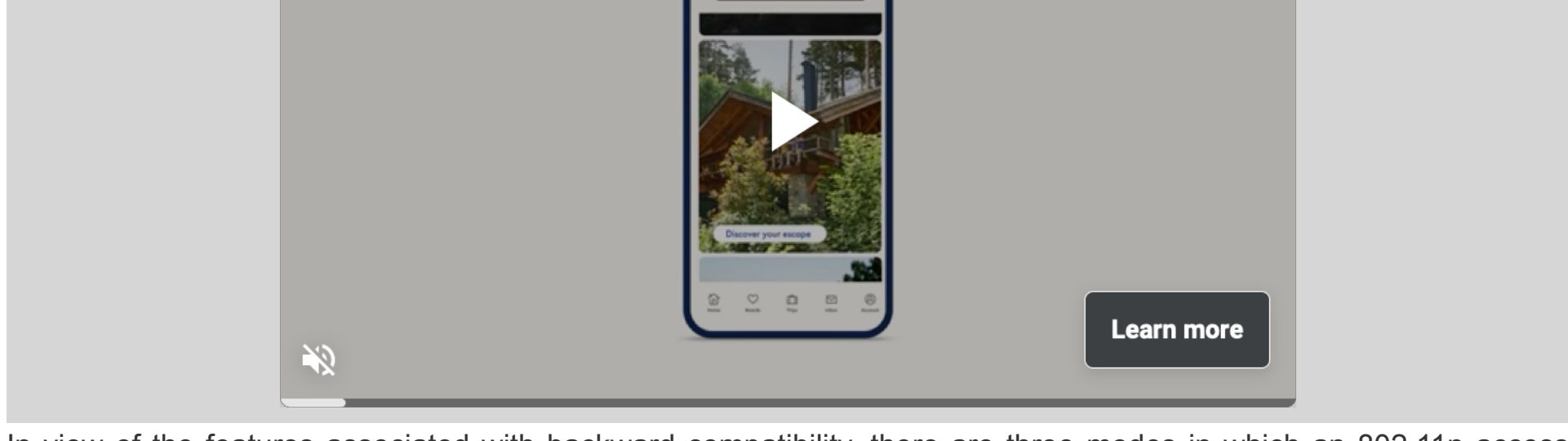
- Changes to implementation of OFDM
- Introduction of MIMO
- MIMO power saving
- Wider channel bandwidth
- Antenna technology
- Reduced support for backward compatibility under special circumstances to improve data throughput

Although each of these new innovations adds complexity to the system, much of this can be incorporated into the chipsets, enabling a large amount of the cost increase to be absorbed by the large production runs of the chipsets.

Backward compatibility switching

802.11n provides backward compatibility for devices in a net using earlier versions of Wi-Fi, this adds a significant overhead to any exchanges, thereby reducing the data transfer capacity. To provide the maximum data transfer speeds when all devices in the wireless local area network are operating on the 802.11n standard, the backwards compatibility feature can be removed.

When earlier devices enter the wireless LAN, the backward compatibility overhead and features are re-introduced. As with 802.11g, when earlier devices enter a network, the operation of the whole wireless LAN is considerably slowed. Therefore operating a net in 802.11n only mode offers considerable advantages.



In view of the features associated with backward compatibility, there are three modes in which an 802.11n access point can operate:

- Legacy (only 802.11 a, b, and g)
- Mixed (both 802.11 a, b, g, and n)
- Greenfield (only 802.11 n) - maximum performance

By implementing these modes, 802.11n is able to provide complete backward compatibility while maintaining the highest data rates. These modes have a significant impact on the physical layer, PHY and the way the signal is structured.

802.11n signal / OFDM implementation

This version of the Wi-Fi wireless LAN standard uses OFDM to provide the various parameters required.

Note on OFDM:

Orthogonal Frequency Division Multiplex, OFDM is a form of signal format that uses a large number of close spaced carriers that are each modulated with low rate data stream. The close spaced signals would normally be expected to interfere with each other, but by making the signals orthogonal to each other there is no mutual interference. The data to be transmitted is shared across all the carriers and this provides resilience against selective fading from multi-path effects.

Read more about **OFDM, Orthogonal Frequency Division Multiplexing.**

The way that OFDM has been used, has been tailored to enable it to fulfil the various requirements for 802.11n.

To achieve this, two new formats are defined for the PHY Layer Convergence Protocol, PLCP, i.e. the Mixed Mode and the Green Field. These are called High Throughput, HT formats. In addition to these HT formats, there is also a legacy duplicate format. This duplicates the 20MHz legacy packet in two 20MHz halves of the overall 40MHz channel.

The signal formats are changed according to the mode in which the system is operating:

- **Legacy Mode:** This may occur as either a 20 MHz signal or a 40 MHz signal:
 - **20 MHz:** In this mode the 802.11n signal is divided into 64 sub-carriers. 4 pilot signals are inserted in sub-carriers -21, -7, 7 and 21. In the legacy mode, signal is transmitted on sub-carriers -26 to -1 and 1 to 26, with 0 being the centre carrier. In the HT modes signal is transmitted on sub-carriers -28 to -1 and 1 to 28.
 - **40 MHz:** For this transmission two adjacent 20MHz channels are used and in this instance the channel is divided into 128 sub-carriers. 6 pilot signals are inserted in sub-carriers -53, -25, -11, 11, 25, 53. Signal is transmitted on sub-carriers -58 to -2 and 2 to 58.

In terms of the frames that are transmitted, they conform to the legacy 802.11a/g OFDM format.

- **Mixed Mode:** In this 802.11n mode, packets are transmitted with a preamble compatible with the legacy 802.11a/g. The rest of the packet has a new MIMO training sequence format.
- **Greenfield Mode:** In the Greenfield mode, high throughput packets are transmitted without a legacy compatible part. As this form of packet does not have any legacy elements, the maximum data throughput on the wireless LAN is much higher.

802.11n MIMO

In order to be able to carry very high data rates on the wireless LAN, often within an office or domestic environment, 802.11n has utilised MIMO. This gives the maximum use of the available bandwidth.

Note on MIMO:

MIMO is a form of antenna technology that uses multiple antennas to enable signals travelling via different paths as a result of reflections, etc., to be separated and their capability used to improve the data throughput and / or the signal to noise ratio, thereby improving system performance.

Read more about **MIMO technology**

The 802.11n standard allows for up to four spatial streams to give a significant improvement in the available data rate available as it allows a number of different data streams to be carried over the same channel.

As might be expected, the number of data streams and hence the overall data capacity is limited by the number of spatial streams that can be carried - one of the limits for this is the number of antennas that are available at either end.



To give a quick indication of the capability of a given system or radio a simple notation may be used. It is of the form: a x b : c. Where a is the maximum number of transmit antennas or RF chains at the transmitter, b is the maximum of receive antennas or receive RF chains; and c is the maximum number of data spatial streams.

An example might be 2 x 4 : 2 would be for a radio that can transmit on two antennas and receive on four, but can only send or receive two data streams.

The 802.11n standard allows for systems with a capability of up to 4 x 4 : 4. However common configurations that are in use include 2 x 2 : 2; 2 x 3 : 2; 3 x 2 : 2. These configurations all have the same data throughput capability and only differ by the level of diversity provided by the antennas. A further configuration of, 3 x 3 : 3 is becoming more widespread because it has a higher throughput, because of the extra data stream that is present.

Power saving

One of the problems with using MIMO is that it increases the power of the hardware circuitry. More transmitters and receivers need to be supported and this entails the use of more current.

While it is not possible to eliminate the power increase resulting from the use of MIMO in 802.11n, it is possible to make the most efficient use of it.

Data is normally transmitted in a "bursty" fashion. This means that there are long periods when the system remains idle or running at a very slow speed. During these times when MIMO is not required, the circuitry can be held inactive so that it does not consume power.

Increased bandwidth

The bandwidth for any wireless communications system is crucial. It is one of the main parameters that determines the maximum bandwidth that can be obtained. Accordingly with wireless LAN systems needing to accommodate much higher levels of data and with faster data rates, the bandwidth is very important.

An optional mode for the new 802.11n chips is to run using a double sized channel bandwidth. Previous systems used 20 MHz bandwidth, but the new ones have the option of using 40 MHz.

The main trade-off for this is that there are less channels that can be used for other devices. There is sufficient room at 2.4 GHz for three 20 MHz channels, but only one 40 MHz channel can be accommodated. Thus the choice of whether to use 20 or 40 MHz has to be made dynamically by the devices in the net.

Antenna technology

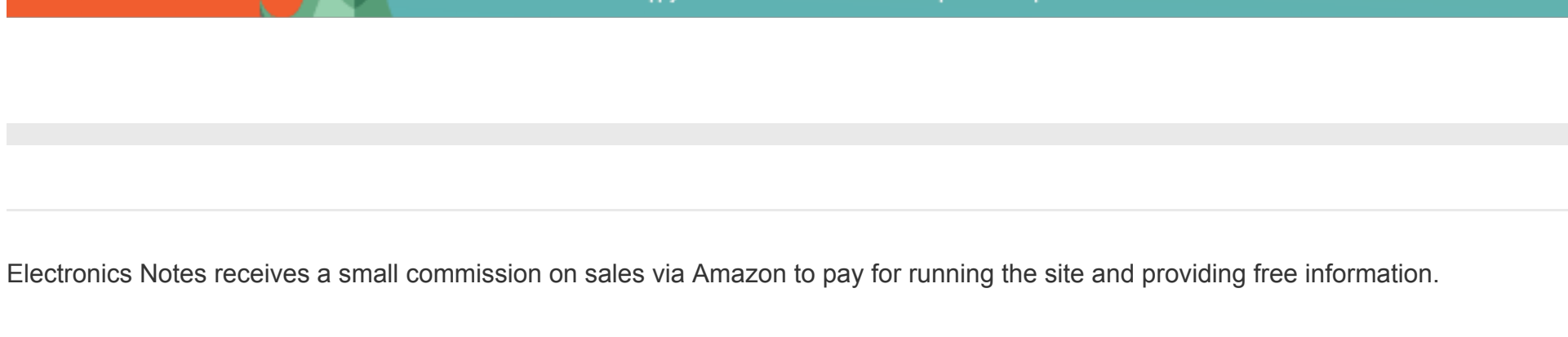
For 802.11n, the antenna associated technologies have been significantly improved by the introduction of beam forming and diversity.

Beam forming focuses the radio signals directly along the path for the receiving antenna to improve the range and overall performance. A higher signal level and better signal to noise ratio will mean that the full use can be made of the channel.

Diversity uses the multiple antennas available and combines or selects the best subset from a larger number of antennas to obtain the optimum signal conditions. This can be achieved because there are often surplus antennas in a MIMO system. As 802.11n supports any number of antennas between one and four, it is possible that one device may have three antennas while another with which it is communicating will only have two. The supposedly surplus antenna can be used to provide diversity reception or transmission as appropriate.

The introduction of IEEE 802.11n was a major step forwards in wireless LAN technology. It enabled Wi-Fi to keep up with the rising demands required by the increasing number of Wi-Fi enabled smartphones and other electronic devices.

802.11n pioneered a number of new technologies that were carried forwards into later versions of the 802 Wi-Fi standard, and many electronic devices continued to use it for many years afterwards.



FOLLOW



27 JANUARY 2023

Fact of the day: It was on this day in 1880 that Thomas Edison filed his patent for an electric incandescent lamp

Quote:
It is amazing what you can accomplish if you do not care who gets the credit.
Harry S Truman

The way things are: When all else fails, read the instructions.

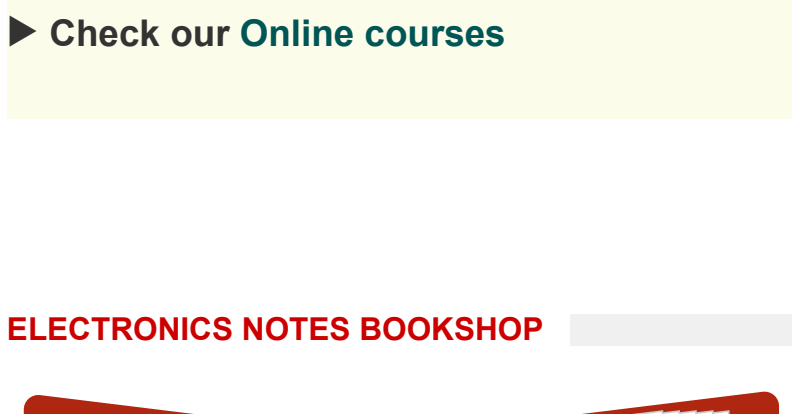
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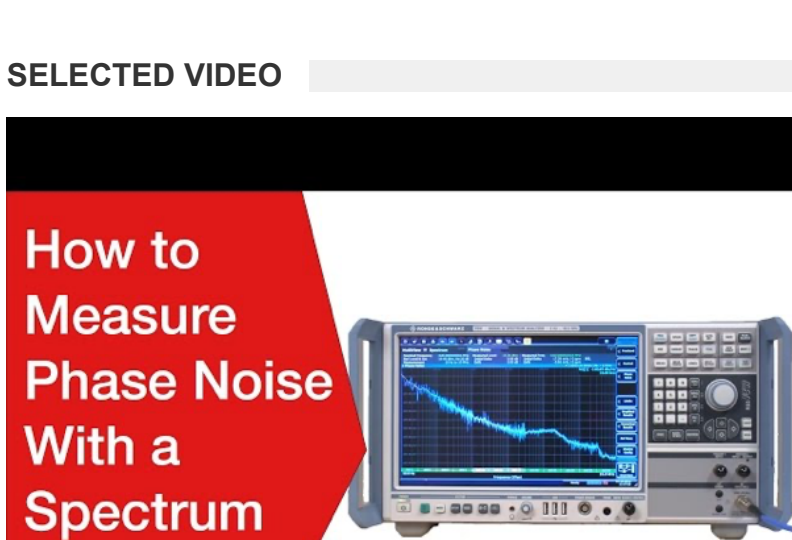
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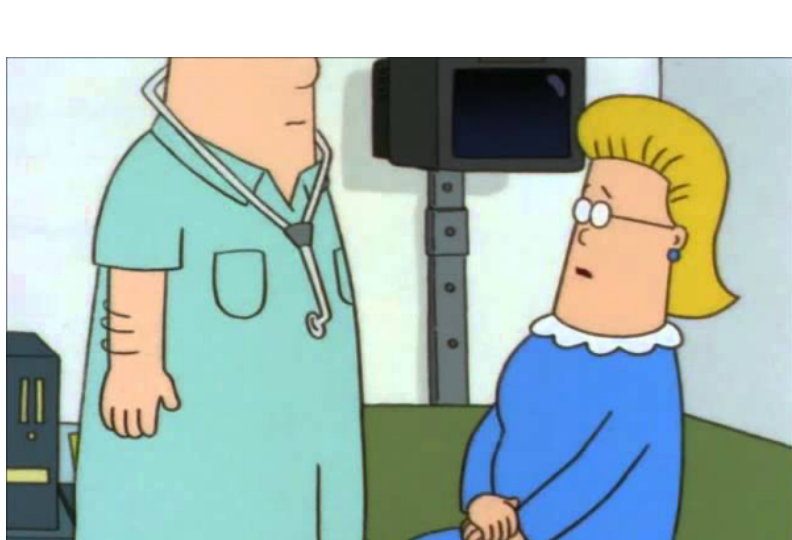
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