Slides from a presentation given by Greg Ennis

at Santa Clara University on August 30, 2023

Sponsored by IEEE Communications Society
Santa Clara Chapter

Wi-Fi Past Present Future

GREG ENNIS

AUGUST 30, 2023

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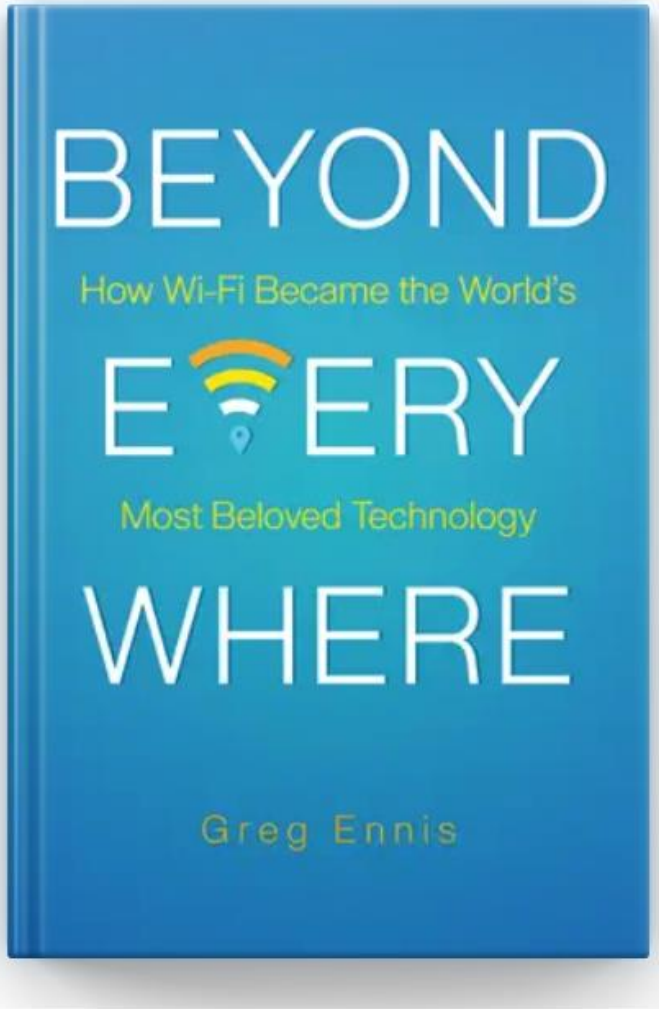
First, some thank yous

- Santa Clara University
- Behnam Dezfouli
- IEEE Communications Society, Santa Clara Chapter

www.gregennis.net



The material in this presentation is drawn from my book

Beyond Everywhere
How Wi-Fi Became the World's Most Beloved Technology

By Greg Ennis

from Post Hill Press

available at amazon.com

//amzn.to/3XZYQXS

and at BARNES&NOBLE

//bit.ly/3sELmoZ

Someone needed to write this book – why me?

- I was privileged to have a front row seat at the center of the Wi-Fi industry for over 25 years
- Author of 1993 "DFWMAC" technical proposal (along with two co-authors) that was adopted by IEEE 802.11 as the foundation for the standard
- Chief Technical Editor of original 1997 802.11 standard
- Along with a handful of colleagues founded Wi-Fi Alliance in 1999
- Served in that organization's lead technical position for sixteen years
- Retired in 2016 as Vice President, Technology for the Wi-Fi Alliance

PAST

PRESENT

FUTURE

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PAST

PRESENT

FUTURE

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Over 18 billion Wi-Fi devices in operation worldwide

4 billion additional devices sold each year

Supports over half of all internet traffic

Global Value of Wi-Fi®

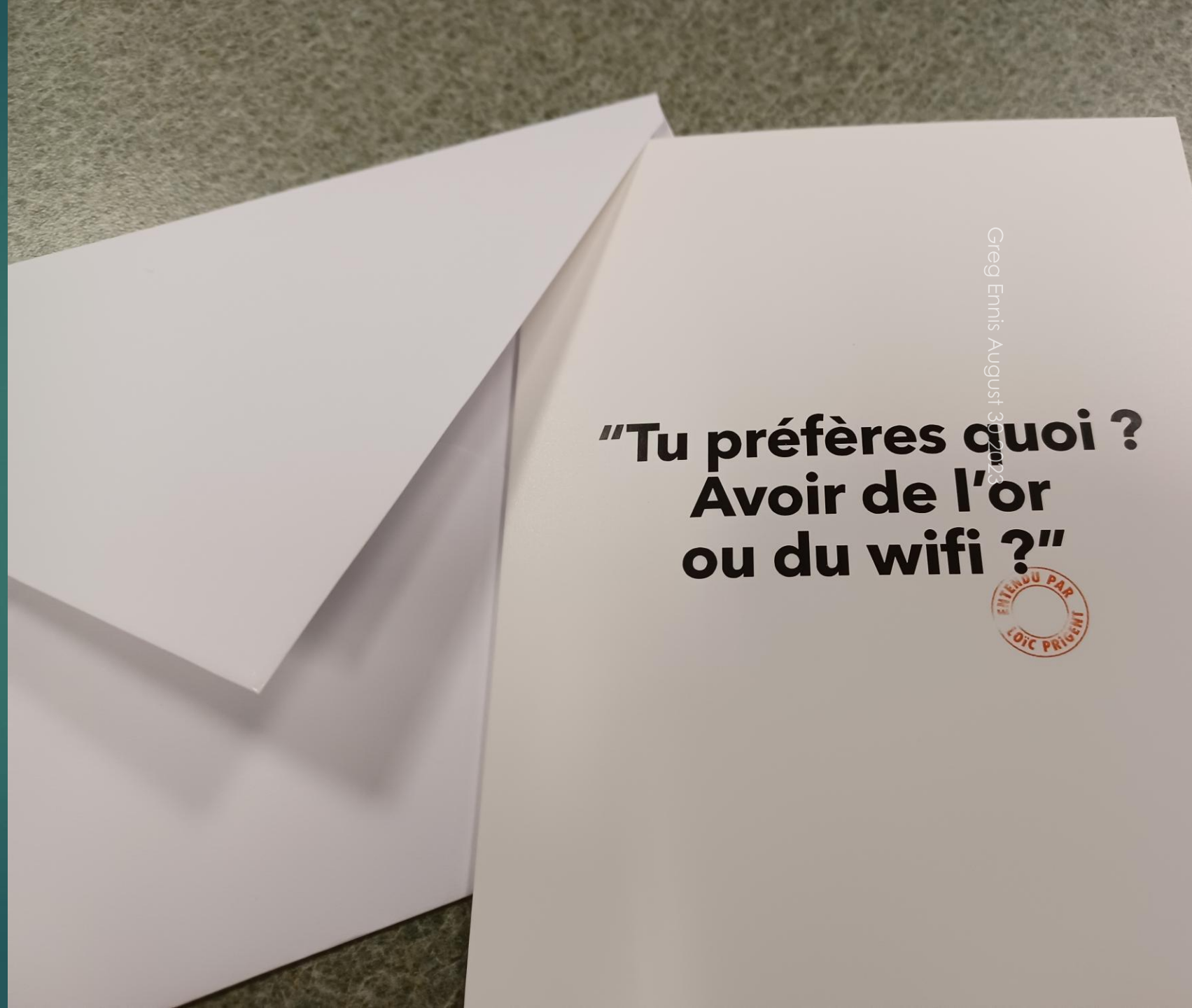
2021 $ 3.3 trillion

2025 $ 4.9 trillion

Telecom Advisory Services, Wi-Fi Alliance®

French greeting card

“Which do you prefer?
Having gold or wifi?”



In every environment

In every country

In every type of device

Wi-Fi is not just a wireless LAN
It's the wireless LAN
There's a universality to Wi-Fi

So the Wi-Fi story is not just about a technology

It's a story about how a technology became a universal language

It's a story about people and their organizations

It's a story about people and their organizations

- Regulatory agencies
- Individual companies
- Standards organizations
- Ad hoc alliances of companies
- Trade associations

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PAST

PRESENT

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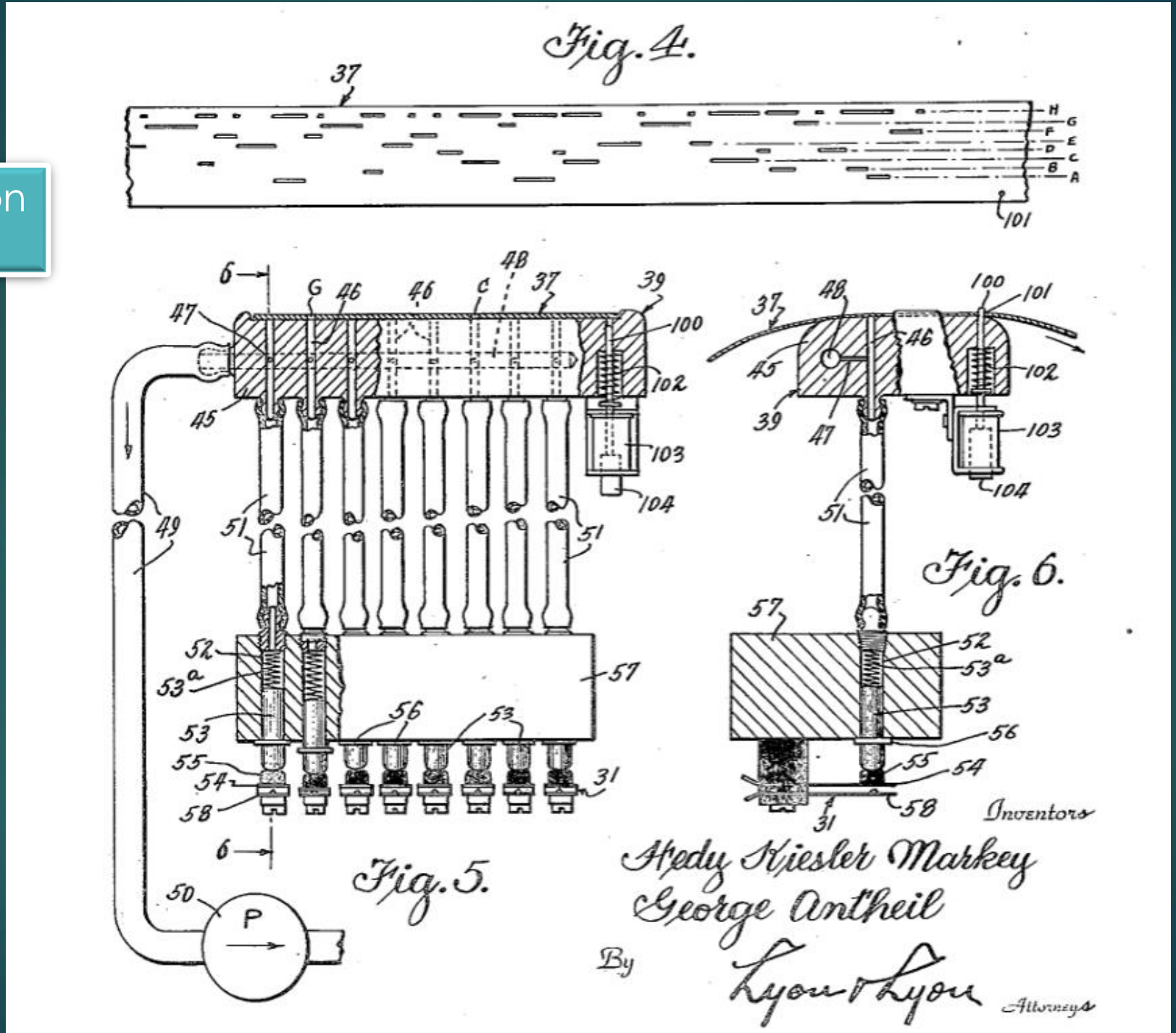
The invention of Wi-Fi?



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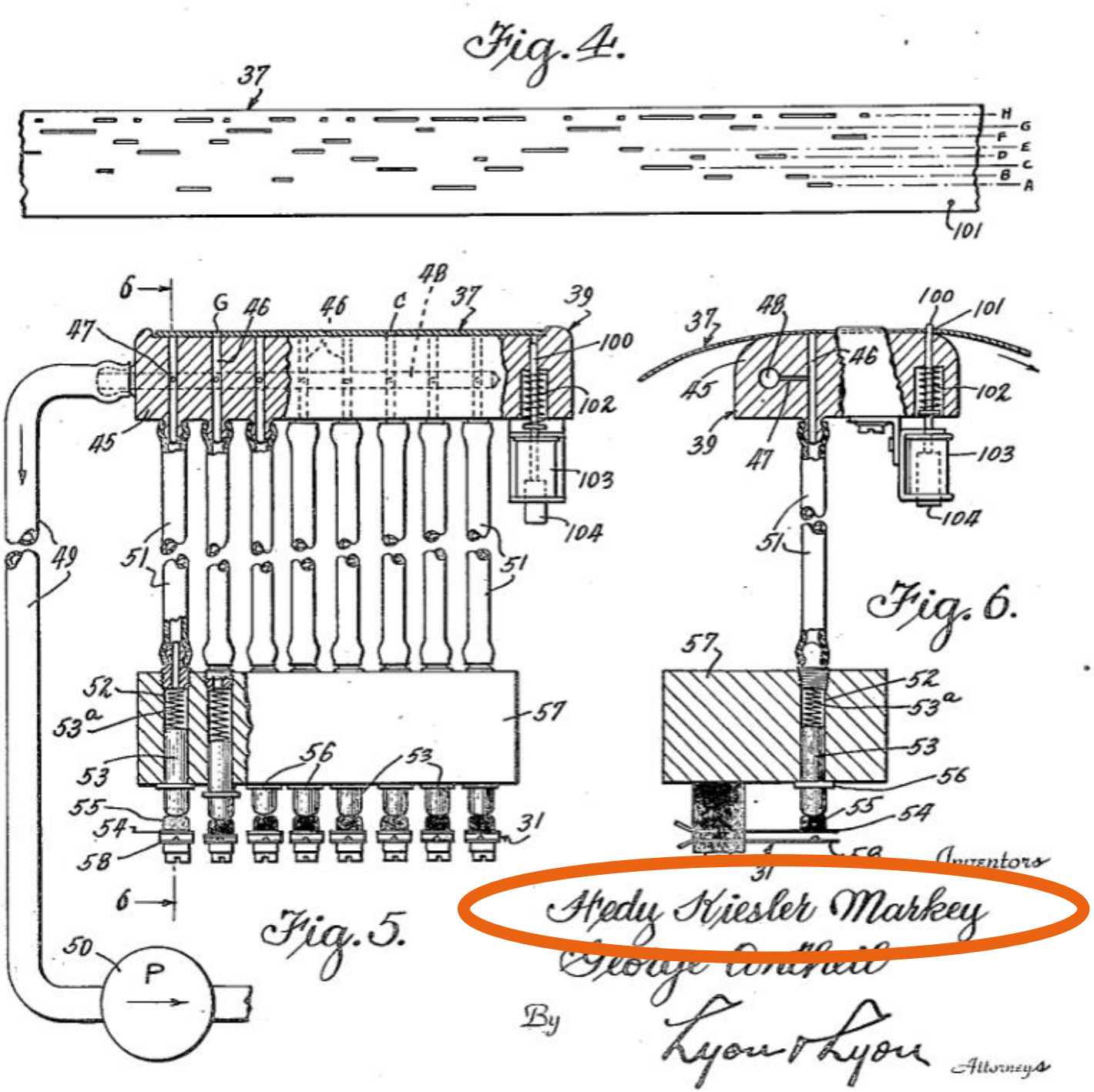

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According to the US Government's National Archives, Hedy Lamarr was the inventor

A blog of the U.S. National Archives

NATIONAL ARCHIVES

Pieces of History

The World War II-Era Actress Who Invented Wi-Fi: Hedy Lamarr

May 26, 2020 By Jessie Kratz, Posted In - World War II

Today's post comes from Lori Norris, an archives technician a the National Archives at College Park.

As we face the uncertainty of the current COVID-19 pandemic, one helpful invention has eased the anxieties of staying at home and assists us daily with our new teleworking lives. Wi-Fi, or wireless fidelity, allows us to stay plugged into the internet while roaming our homes for the perfect spot to type up emails or binge-watch our favorite shows. As with the invention of the computer, the technology that made Wi-Fi possible came about during another devastating global event: World War II. The head inventor wasn't a scientist or engineer, but a famous Hollywood actress with an obsession with tinkering

UNITED STATES PATENT OFFICE

2,292,387

SECRET COMMUNICATION SYSTEM

Hedy Kiesler Markey, Los Angeles, and George Antheil, Manhattan Beach, Calif.

Application June 10, 1941, Serial No. 397,412

6 Claims. (Cl. 250—2)

This invention relates broadly to secret communication systems involving the use of carrier waves of different frequencies, and is especially useful in the remote control of dirigible craft, such as torpedoes.

An object of the invention is to provide a method of secret communication which is relatively simple and reliable in operation, but at the same time is difficult to discover or decipher.

Briefly, our system as adapted for radio control of a remote craft, employs a pair of synchronous records, one at the transmitting station and one at the receiving station, which change the tuning of the transmitting and receiving apparatus from time to time, so that without knowledge of

Fig. 2 is a schematic diagram of the apparatus at a receiving station;

Fig. 3 is a schematic diagram illustrating a starting circuit for starting the motors at the transmitting and receiving stations simultaneously;

Fig. 4 is a plan view of a section of a record strip that may be employed;

Fig. 5 is a detail cross section through a record-responsive switching mechanism employed in the invention;

Fig. 6 is a sectional view at right angles to the view of Fig. 5 and taken substantially in the plane VI—VI of Fig. 5, but showing the record strip in a different longitudinal position; and

Fig. 7 is a diagram in plan illustrating how

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Spread Spectrum: Frequency Hopping

- Frequency Hopping is a *spread spectrum* technique
- By hopping around a predetermined sequence of frequency channels the signal is spread over a wider frequency range

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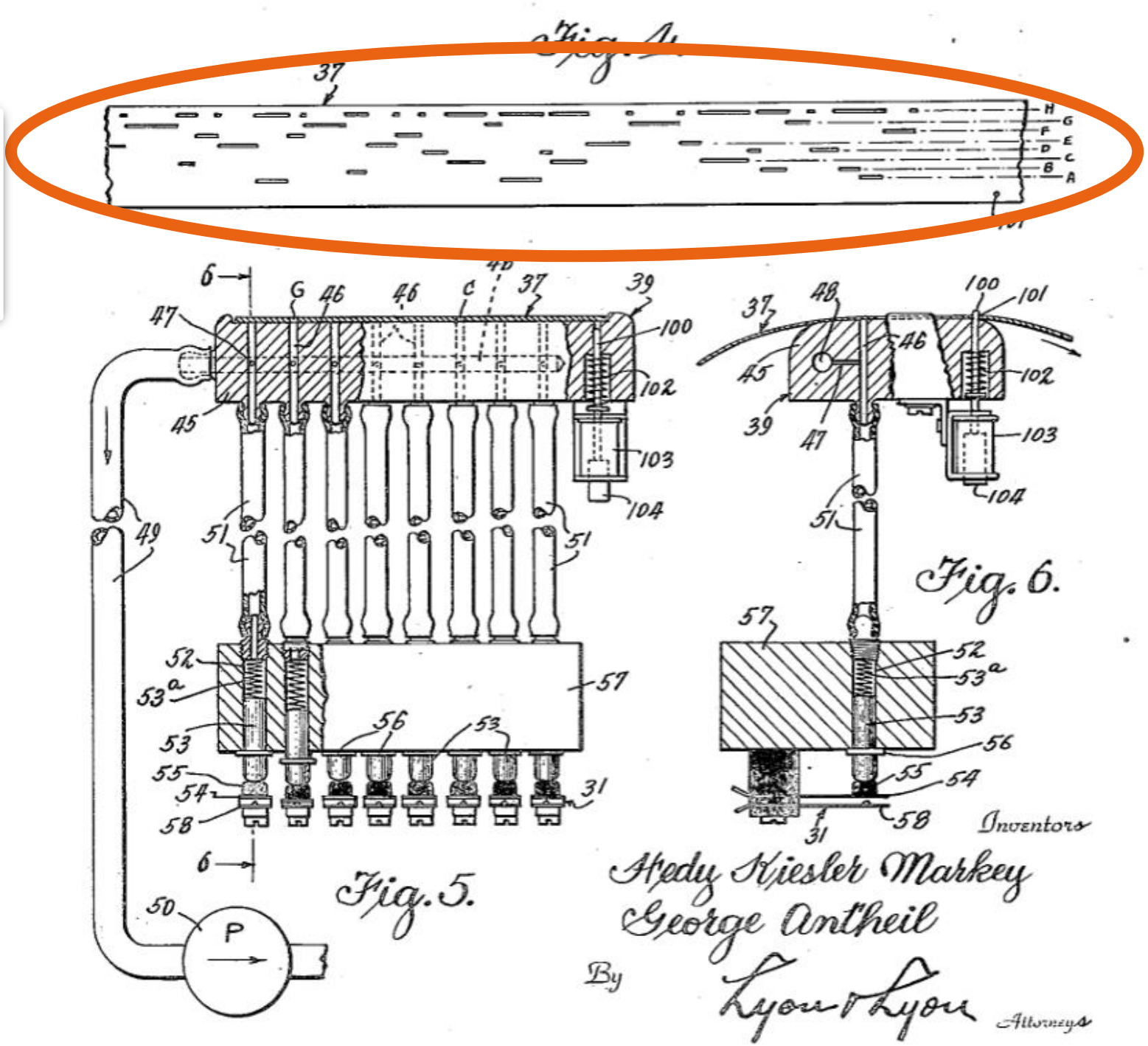
Commanding frequency hops via a player piano roll



Spread Spectrum: Direct Sequence

- The other major spread spectrum technique is known as *Direct Sequence*
- Direct sequence encodes each data bit into a codeword consisting of multiple "chips"

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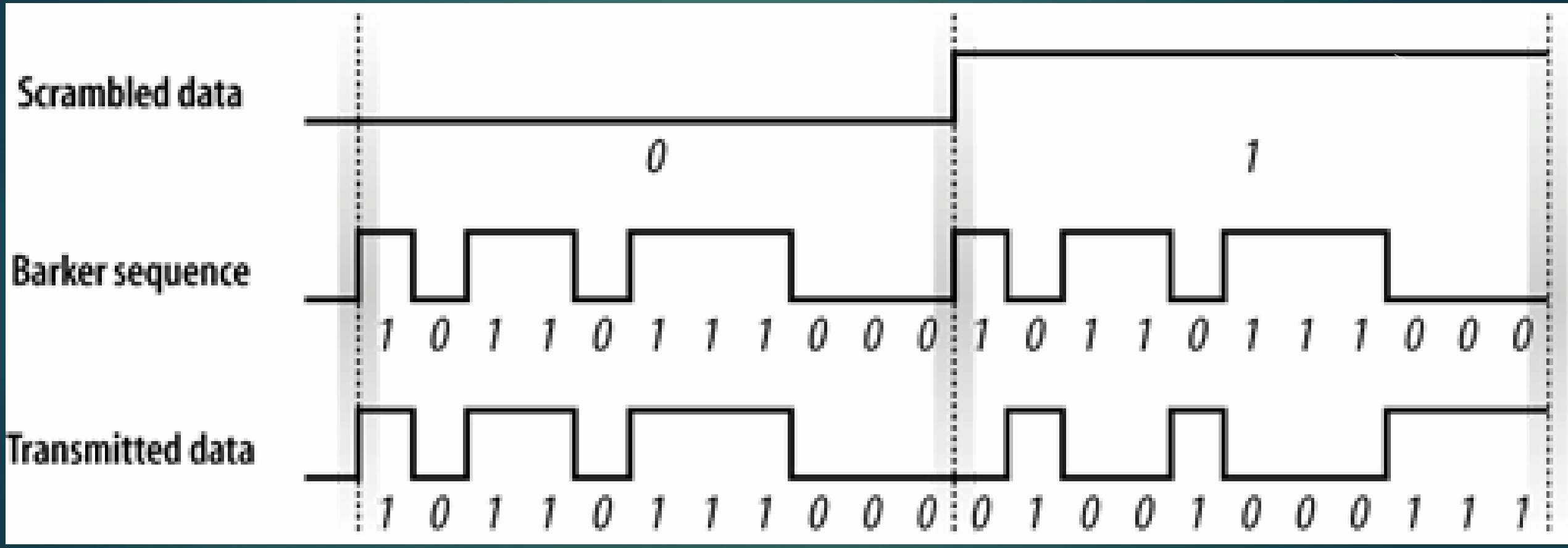
Direct Sequence Example



Wi-Fi originated as a Direct Sequence technology, not Frequency Hopping

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No, Hedy Lamarr did not invent Wi-Fi

- Frequency hopping was incorporated as an optional transmission technique in the original IEEE 802.11 standard
- But in 1999 it was the direct sequence version of spread spectrum, not frequency hopping, that got incorporated into Wi-Fi
- The necessity of supporting frequency hopping did influence the design of the 802.11 MAC protocol

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A blog of the U.S. National Archives

NATIONAL ARCHIVES

Pieces of History

The World War II-Era Actress ~~Who Invented Wi-Fi~~: Hedy Lamarr

May 26, 2020 By Jessie Kratz, Posted In - World War II

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Before the
Federal Communications Commission
Washington, D. C. 20554

FCC 85-245
35747

In the Matter of)
)
)
Authorization of spread spectrum and other) GEN DOCKET NO. 81-413
wideband emissions not presently provided)
for in the FCC Rules and Regulations.)

FIRST REPORT AND ORDER

Adopted: May 9, 1985 Released: May 24, 1985

By the Commission:

INTRODUCTION AND SUMMARY

1. Spread spectrum modulation is a wideband modulation which was originally developed for military applications but which has several interesting civil applications 1/. This technology has been implicitly forbidden by the FCC rules with a few limited exceptions. On June 30, 1981, the Commission adopted a Notice of Inquiry ("Inquiry") 2/ in this proceeding seeking comments on a rule structure that would permit civil use of this technology 3/.

FCC 1985 Report and Order

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Elements of the 1985 ruling

- Allowed devices to transmit without a license in certain frequency bands
  - 2.4 and 5 GHz
- Low power levels
- Must use one of two spread spectrum transmission techniques
  - Frequency hopping
  - Direct sequence

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First FCC approval

Telesystems SLW “ARLAN”

$1500

Telesystems later bought by Telxon

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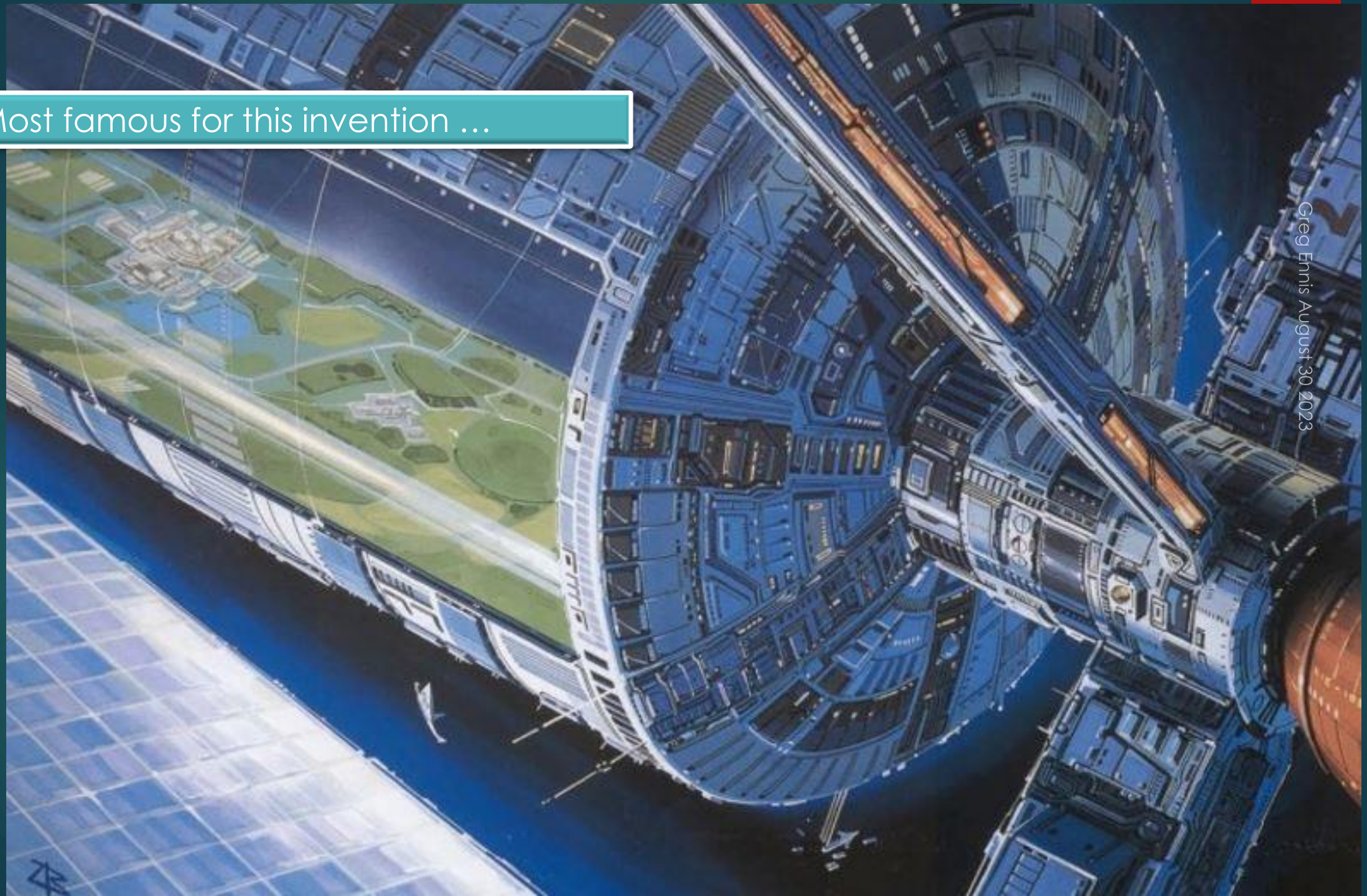
Another Wireless LAN pioneer

Most famous for this invention …



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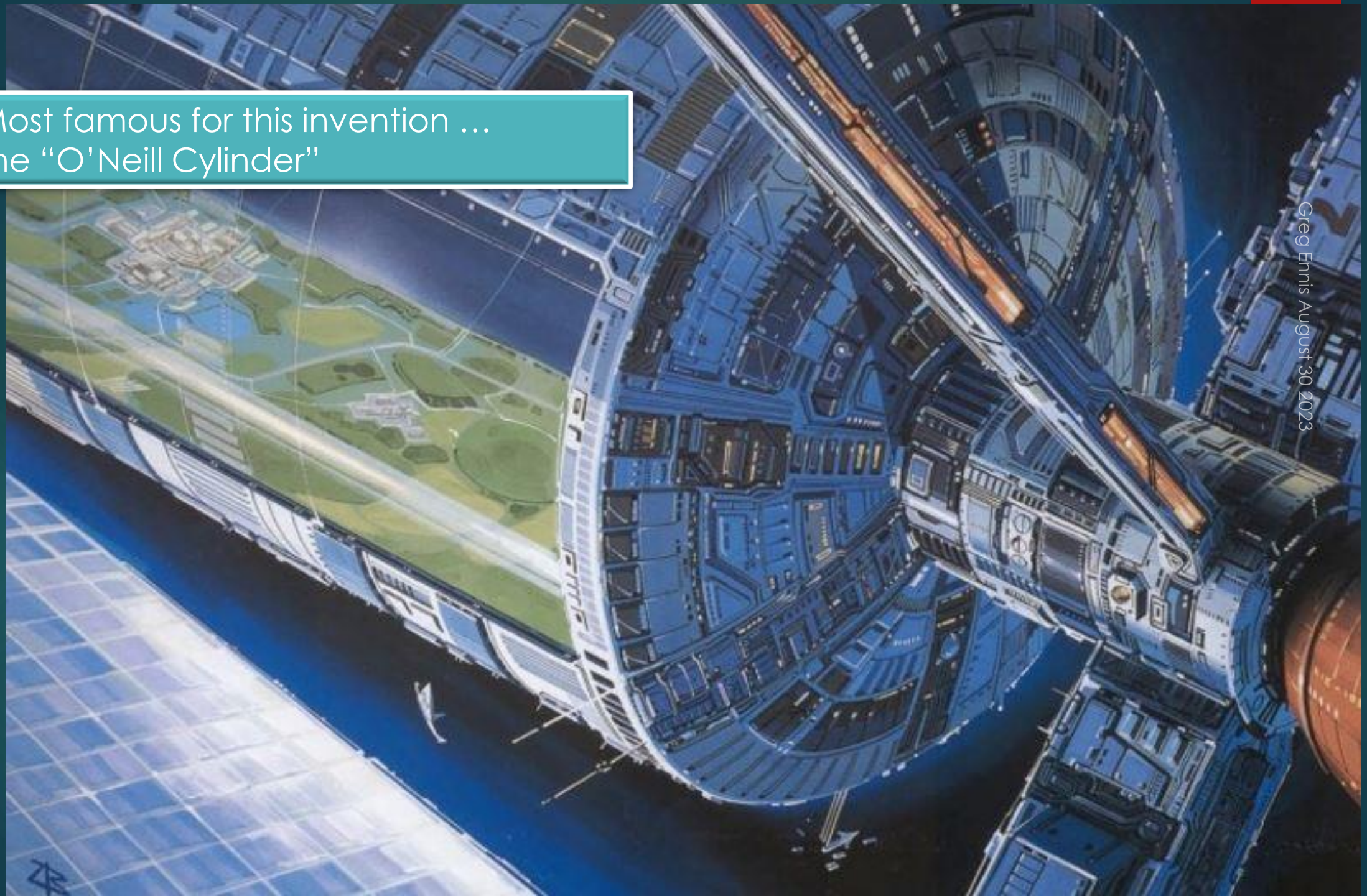
Most famous for this invention …
the "O'Neill Cylinder"



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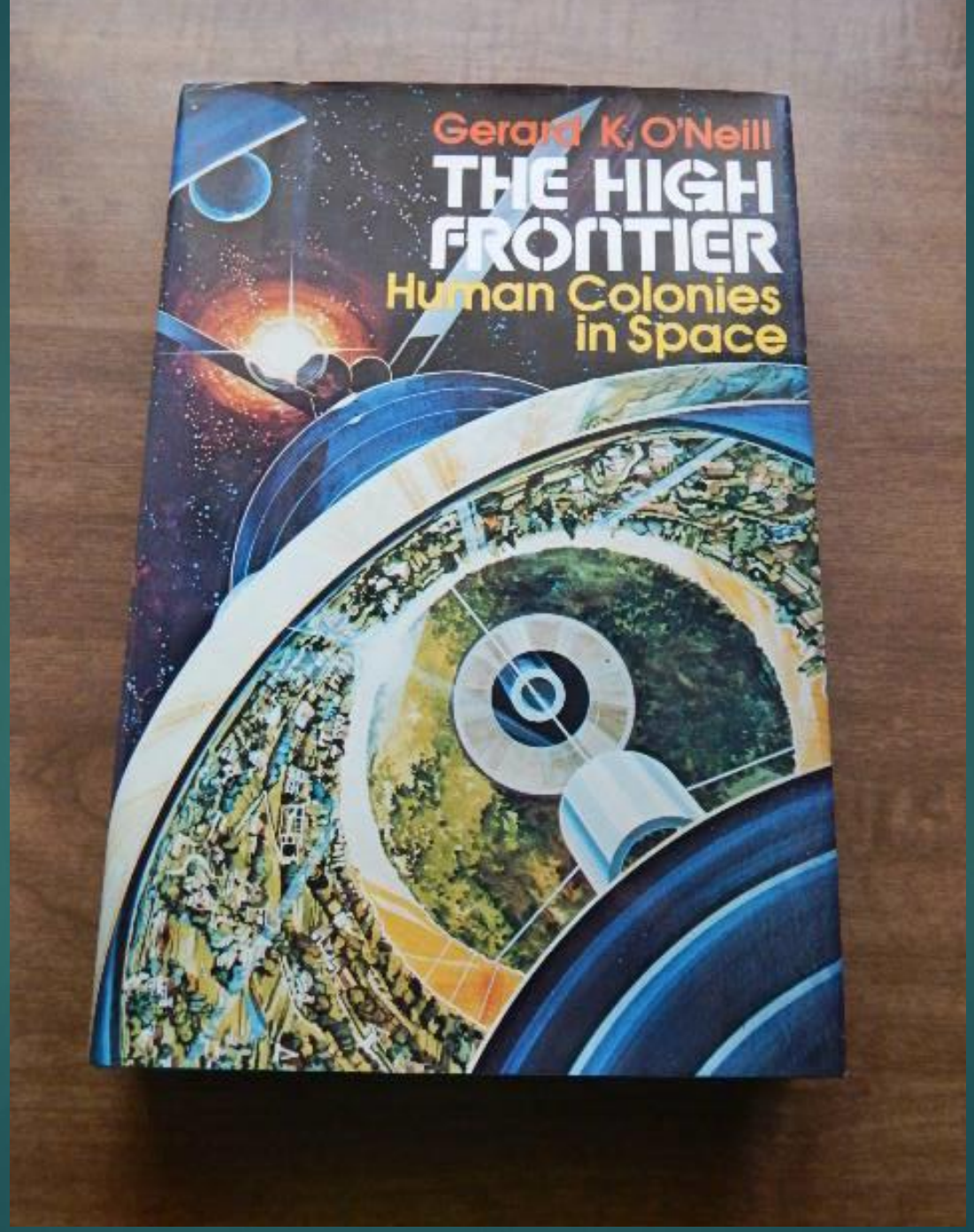
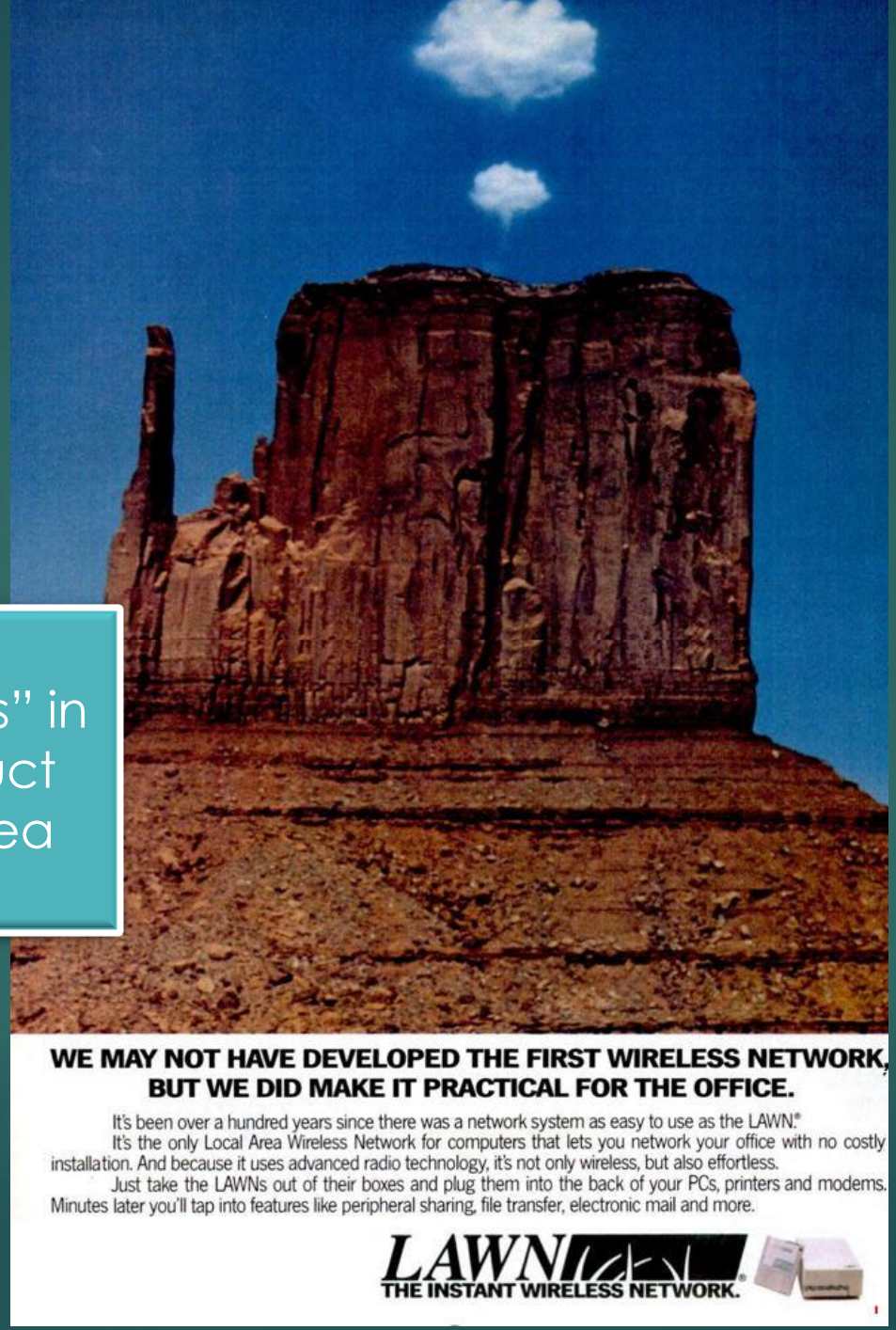
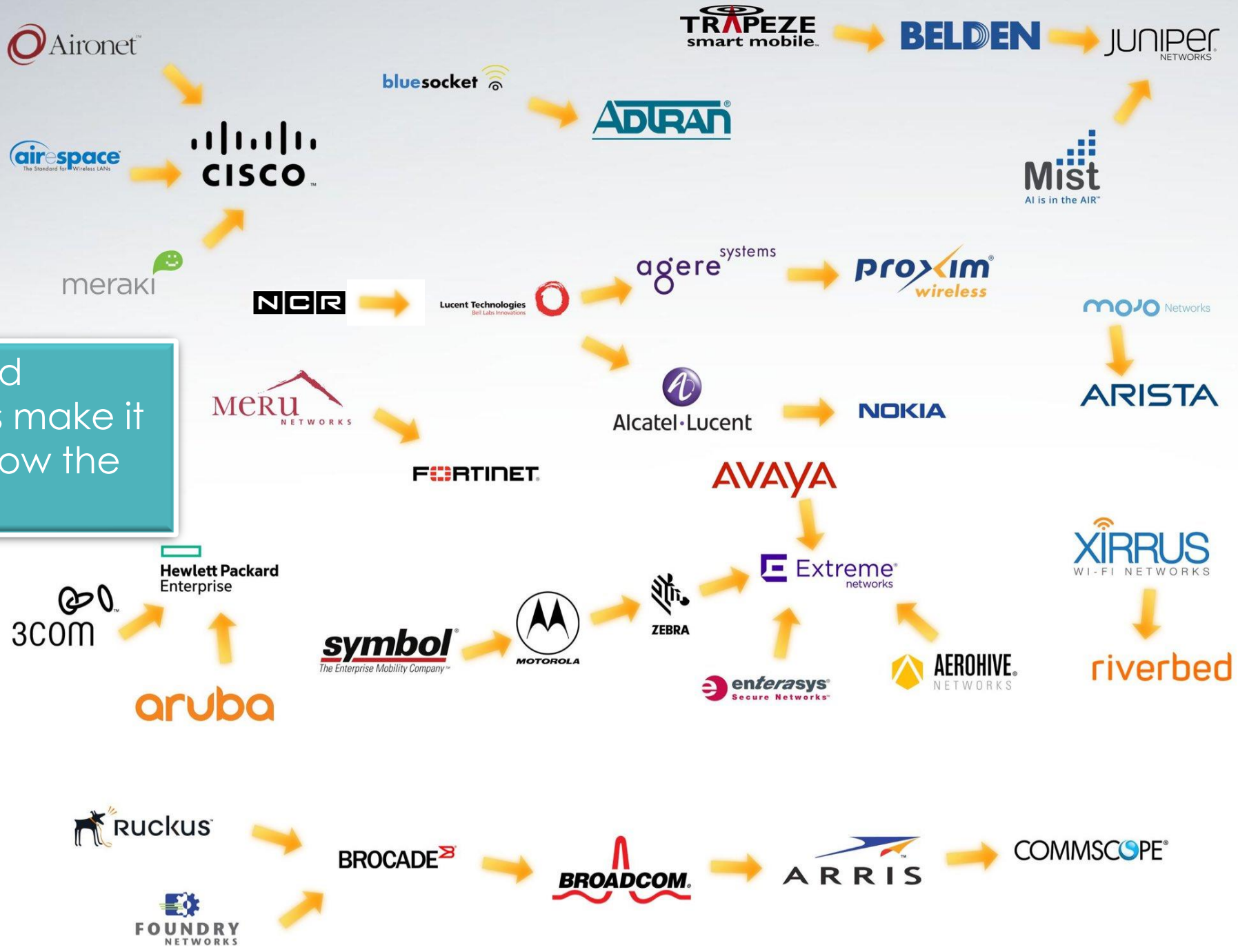
Princeton physicist Gerard O'Neill wrote a popular book in 1976



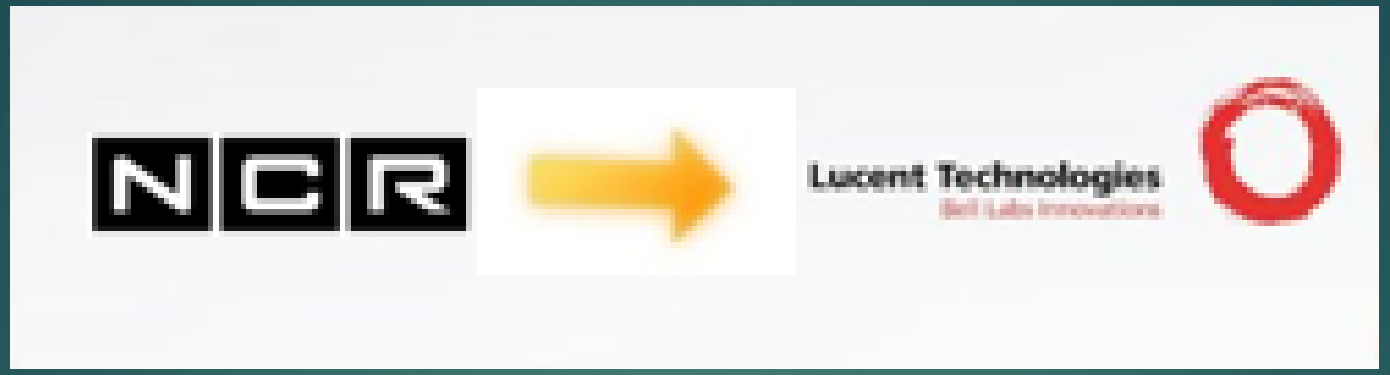
Gerard O'Neill started "O'Neill Communications" in the late 80s, with a product called "LAWN" (Local Area Wireless Network)



By the early 1990s various products were FCC approved and on the market



Mergers and acquisitions make it tricky to follow the story



Two specific acquisitions are particularly noteworthy

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By the early 1990s various products were FCC approved and on the market

Note that Symbol, NCR, and Telxon were all very focused on a specific application

Handheld barcode scanners were the center of attention for the wireless LANs of the early 1990s

Symbol, NCR, and Telxon were all major players in this market

Vertical versus Horizontal Markets

- By 2000, the WLAN industry was focused on the *horizontal* market of general purpose computers
- But the industry focus in early 1990s was on wireless LANs tailored to a specific application: *vertical* markets
  - This was before the internet was pervasive
  - Before DSL
- Example vertical market: wireless barcode scanners (Symbol, Telxon, NCR, …)
- Another example: wireless financial trading terminals

Chicago Board of Trade

Major commodity trading floor – soybeans, pork bellies, cotton, but also financial securities

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CBOT Trading Floor

1989: hand-signals and lots of shouting

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Let's focus on this guy …

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Dietrich Volk, alias Peter Vogel

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Undercover FBI Agent

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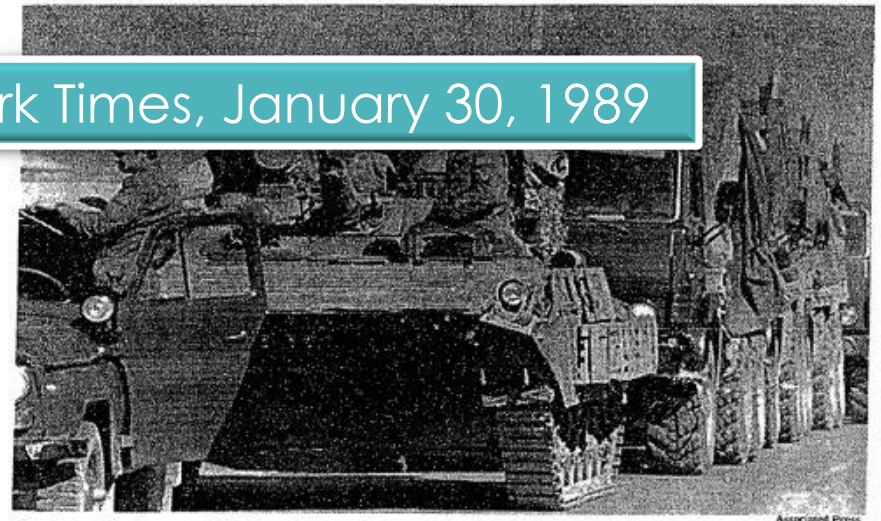
New York Times, January 30, 1989

"All the News That's Fit to Print"

The New York Times

Late Edition
New York: Today, clearing, breezy, mild. High 45-50. Tonight, clear. Low 32-37. Tomorrow, mostly sunny, windy, very mild. High 49-54. Yesterday: High 52, low 39. Details are on page B6.

VOL.CXXXVIII . . No. 47,766 NEW YORK, MONDAY, JANUARY 30, 1989 50 cents beyond 75 miles from New York City, except on Long Island. 35 CENTS



Associated Press

As Soviets Leave Afghanistan, Fear of New Civil War

A convoy heading out of Kabul on Saturday as the Soviet pullout continued. Richard W. Murphy, a State Department Middle East expert, voiced concern that if the Soviet-backed Afghan Government falls, the Afghan insurgent factions may turn against each other. Page A3.

F.B.I. Commodities 'Sting': Fast Money, Secret Lives

The following article is based on reporting by Eric N. Berg, Kurt Eichenwald and Julia Flynn Siler and was written by Mr. Berg.

Special to The New York Times

CHICAGO, Jan. 29 — Few people at the Chicago Board of Trade took notice in December 1986 when a stocky man, who combed strands of hair over his head to conceal a bald spot, began working on the trading floor as a telephone clerk.

The man, who called himself Richard Lee Carlson, "looked like a guy who could be in an Allstate insurance ad," one broker said. "He was harmless looking."

Today, few in this city's teeming financial district would call Mr. Carlson harmless. He was one of at least four undercover agents of the Federal Bureau of Investigation who set out nearly two years ago to substantiate allegations of widespread corruption in commodities futures trading at the Board of Trade, the world's largest futures market, and at the Chicago Mercantile Exchange, the second-largest.

Fictitious World

In an elaborate "sting" operation, the agents built a fictitious world for themselves in order to pose as traders and secretly tape-record hundreds of conversations with commodities traders. Some traders were suspected of overcharging customers, not paying them the full proceeds of sales and using their knowledge of customer orders to trade first for themselves.

The Government's ruse was disclosed about two weeks ago, when the agents and prosecutors subpoenaed at least 50 traders and others to appear before a Federal grand jury. Hundreds of other subpoenas have been issued, involving millions of pages of documents.

Suddenly it was as if the people the agents portrayed had never existed. As the sting became

Continued on Page D6, Column 1

United Press International

Chicago Mercantile Exchange, one exchange investigated in the "sting" operation.

BUSH IS CRITICIZED FOR NOT DROPPING SAVINGS-FEE PLAN

WIDE OPPOSITION SEEN

2 Senators Say Idea Is Dead in Congress, but Officials Reaffirm It's an Option

By PETER T. KILBORN
Special to The New York Times

WASHINGTON, Jan. 29 — Bankers and members of Congress criticized the Bush Administration today for insisting that a fee on deposits remains an option to rescue the savings and loan industry.

A prominent banker, Willard C. Butcher, chairman and chief executive of the Chase Manhattan Corporation, issued a statement calling the deposit fee "unsound public policy." And both Democratic and Republican members of the Senate Banking Committee expressed concern about the proposal, which would require the approval of the Democratic-controlled Congress.

Senator James R. Sasser, a Tennessee Democrat, noting the "overwhelmingly bipartisan objection" to a fee, said, "For all practical purposes the proposal is politically dead."

"It's like saying that a patient who died on the operating table is expected to fully recover," said Senator John Heinz, a Pennsylvania Republican.

Reaction to Saturday Comments

The reaction was prompted by the statements of Administration officials on Saturday that they were determined to stick with the option of requiring the banking industry and its customers to help pay to resolve the savings crisis.

At that time, the White House chief of staff, John H. Sununu, said he wanted to rebut previous Administration statements indicating that the fee proposal had been abandoned. Mr. Sununu said that as far as the White House was con-

FOES OF PINOCHET FEUDING OVER VOTE

Chile Opposition Split on Who Should Run for President

By SHIRLEY CHRISTIAN
Special to The New York Times

SANTIAGO, Chile, Jan. 29 — Four months after Gen. Augusto Pinochet lost a bid to extend his presidency by eight years, the political forces that led the campaign against him are themselves divided and feuding over whom to nominate for president.

"We are caught up in a big mess," said Genaro Arriagada, who as executive secretary of the 16-party coalition

Lebanon's Multiplying Rivalries Move Nation Closer to Breakup

By JOHN KIFNER
Special to The New York Times

NICOSIA, Cyprus — Lebanon is sinking ever closer to disintegration in the worst crisis of its 14 years of civil war.

The latest three weeks of fighting between rival Muslims in the southern slums of Beirut and in hilltop villages southeast of the port of Sidon have left at least 140 people dead.

The 1943 pact that allocated political power among Christian and Muslim sects — with Maronite Catholics guaranteed predominance — appears to have come apart for good.

Moreover, both Muslim and Christian camps are divided internally, and the only likely prospect seems to be more bloodshed.

On the Christian side, hard-line mili-

On the Muslim side, the branch that is now largest, the roughly 1.5 million Shiites, is divided in a brutal war for control that has raged for months in southern Lebanon and in the Beirut shantytowns.

"There is no real common denominator anymore," an Arab journalist in Beirut said. "After 14 years, violence has become a way of life, and we are disintegrating, fragmenting, into civil wars within civil wars."

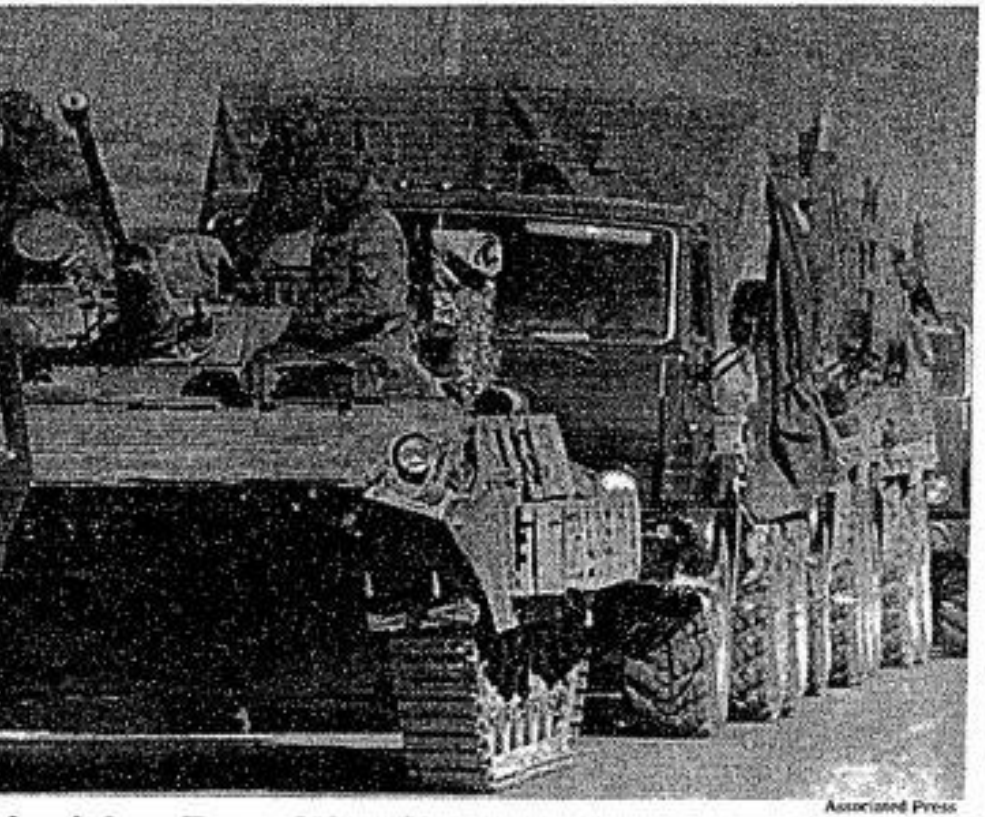
Departure of Amin Gemayel

The departure of President Amin Gemayel, once the bright hope of American policy, at the end of his six-year term last fall plunged Lebanon into

Money Bush Wants for Drug War Is Less Than Sought by Congress

By BERNARD WEINRAUB
Special to The New York Times

47,766 Copyright © 1989 The New York Times NEW YORK, MONDAY, JANUARY 30, 1989 50 cents beyond 75 miles from New York City, except on Long Island 35 CENTS



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Reaction to Saturday Comments

Operation Sourmash

- FBI Sting Operation in 1989 targeting corrupt commodity traders at the Chicago Board of Trade and the Chicago Mercantile Exchange
- Resulted in indictments, convictions, financial penalties

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- But the most important long term impact:

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- But the most important long term impact:

The Federal Government forced the exchanges to replace their fraud-prone manual system with a network of wireless trading terminals

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(May 6 1996)TRADERS USE ELECTRONIC TRADING CARDS IN THE WHEAT FUTURES PIT. HANDOUT PHOTO, NO CREDIT.
SLUG:BW 0507 DDB 01 01 FUTURES 45 X29 RW
AP LEAFDESK

AP LEAFDESK

Operation Sourmash

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- But the most important long term impact:

This CBOT wireless system was a major progenitor of Wi-Fi and involved several of the primary players in the subsequent development of the protocol

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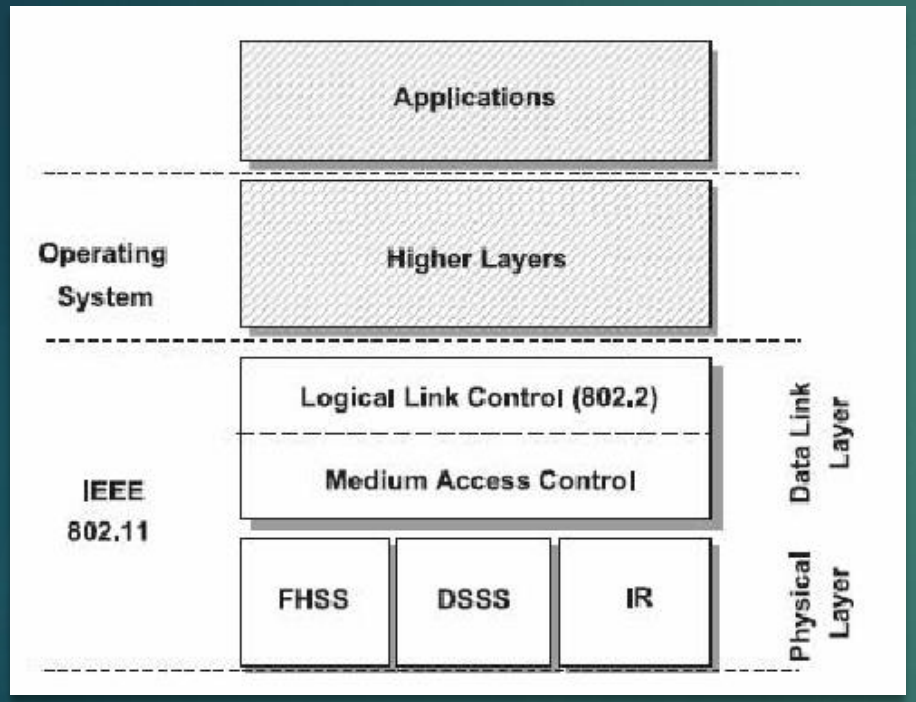
Concurrently with CBOT network, NCR was doing some development

- Like Symbol and Telxon, NCR focused on retail/barcode/warehouse
  - But not exclusively
- Development team in Netherlands created "WaveLAN"
- Direct sequence, 2 megabits per second
- NCR was instrumental in the creation of IEEE's 802.11 Working Group
- NCR's Vic Hayes served as the chair from 1990 to 2000

IEEE 802.11 Working Group



- Formed in early 1990s to develop a wireless LAN standard
- Single Medium Access Control (MAC) protocol over multiple Physical Layer (PHY) protocols
- Two spread-spectrum radio PHYs (frequency hopping and direct sequence) and one infrared
- Major initial goal: determination of the MAC foundation protocol

Centralized MAC versus Distributed

Is there a central controller which assigns transmit opportunities to stations?

Or do stations decide among themselves, in a distributed fashion, who gets to transmit when

Centralized MAC versus Distributed

Centralized proponents: IBM, National Semiconductor, Spectrix

Distributed proponents: Symbol, NCR, Xircom

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A joint proposal was developed by Symbol, NCR, and Xircom called "DFWMAC"

IEEE 802.11
Wireless Access Method and Physical Specification

DFWMAC

Distributed Foundation Wireless Medium Access Control

Wim Diepstraten
NCR WCND-Utrecht
NCR/AT&T Network Product Group
Nieuwegein The Netherlands
Tel: (31)-3402-76482
Fax: (31)-3402-39125
Email: Wim.Diepstraten@utrecht.ncr.com

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Fax: (415) 691-1064
Email: pbelange@xircom.com

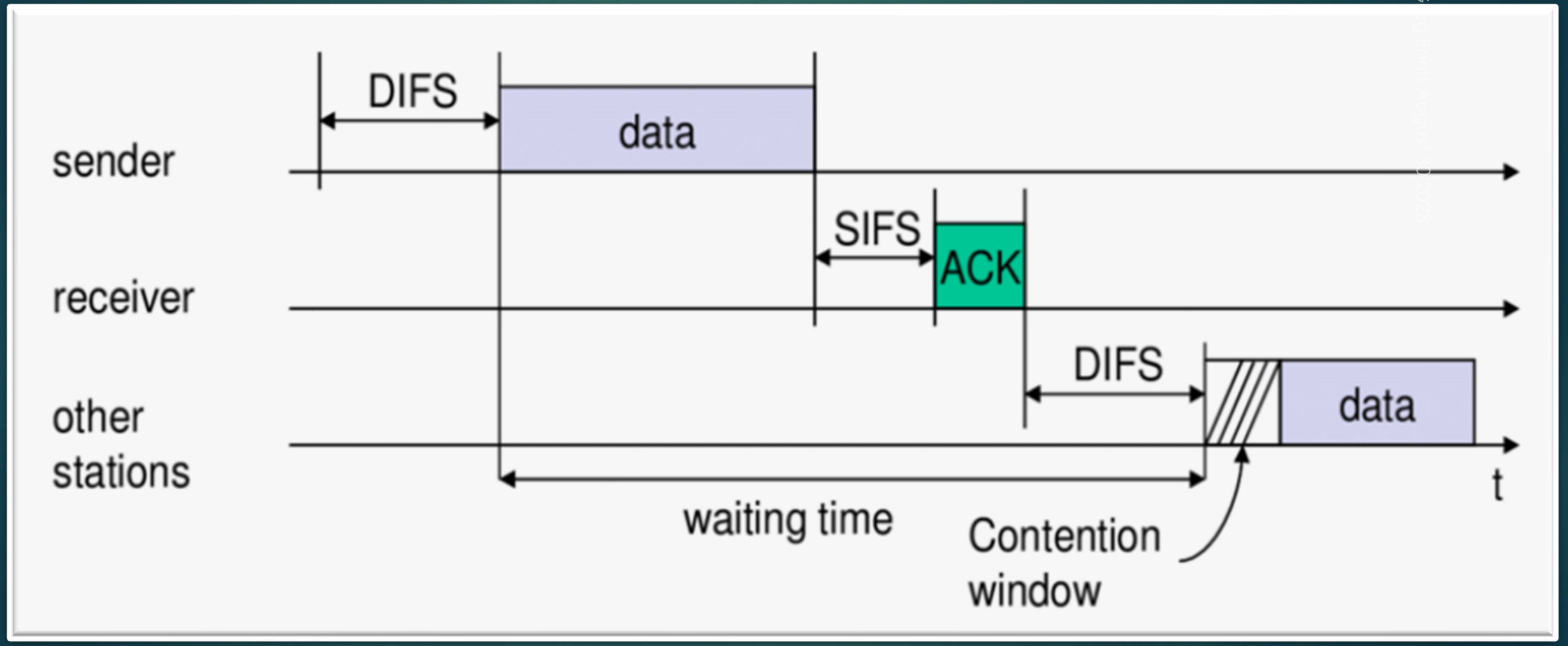
Abstract

This document presents a proposal to IEEE 802.11 for a wireless medium access control protocol. Most of the basic concepts within this document have been presented in several prior submissions to IEEE, known by their acronyms **WMAC** (NCR and Symbol) and **WHAT** (Xircom). The protocol incorporates a simple, distributed coordination function based upon CSMA with collision avoidance, together with an optional point coordination function which provides for contention-free transmissions supporting time-bounded services.

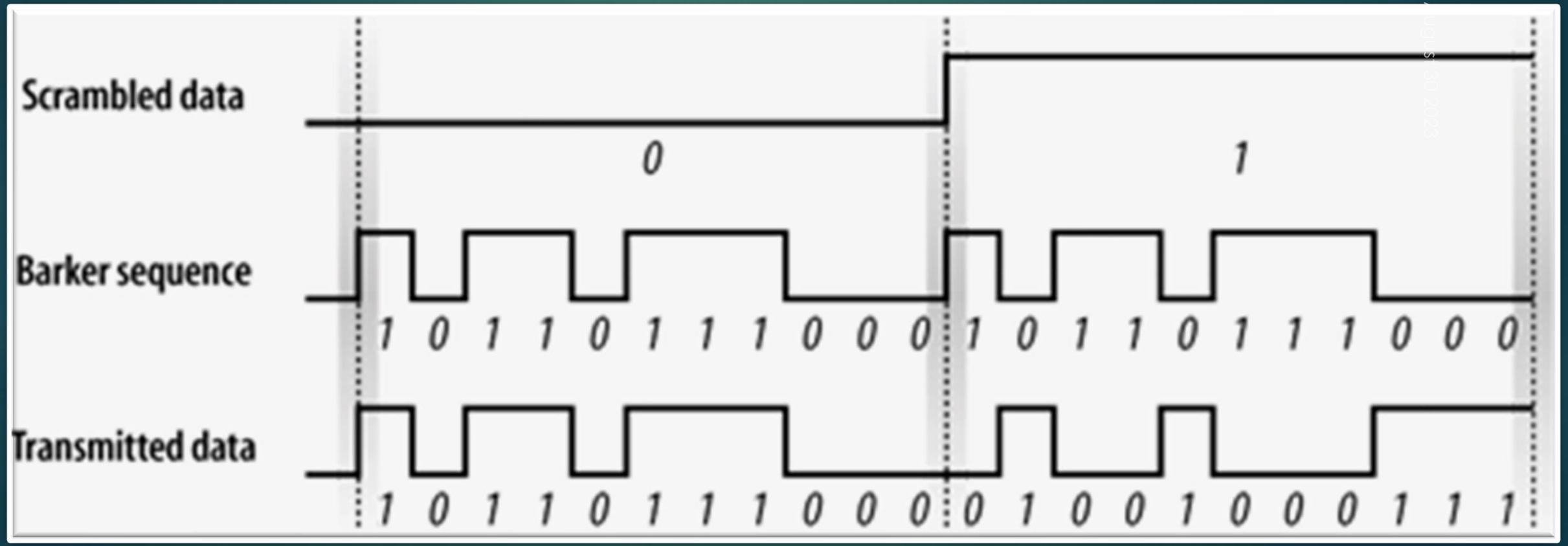
DFWMAC – Adopted as foundation for 802.11 on November 11, 1993

- Distributed Foundation Wireless MAC
  - Joint proposal from Symbol Technologies, NCR, and Xircom
- Key elements:
  - Carrier Sense Multiple Access with Collision Avoidance
    - *with acknowledgment plus optional RTS/CTS*
  - Time synchronization via periodic beacons
  - Power conservation mechanisms
  - Scanning for AP – passive and active (via probes)
  - Management exchanges for establishing connection

CSMA/CA


DIFS
data
sender
SIFS
ACK
receiver
DIFS
data
other
stations
t
waiting time
Contention
window

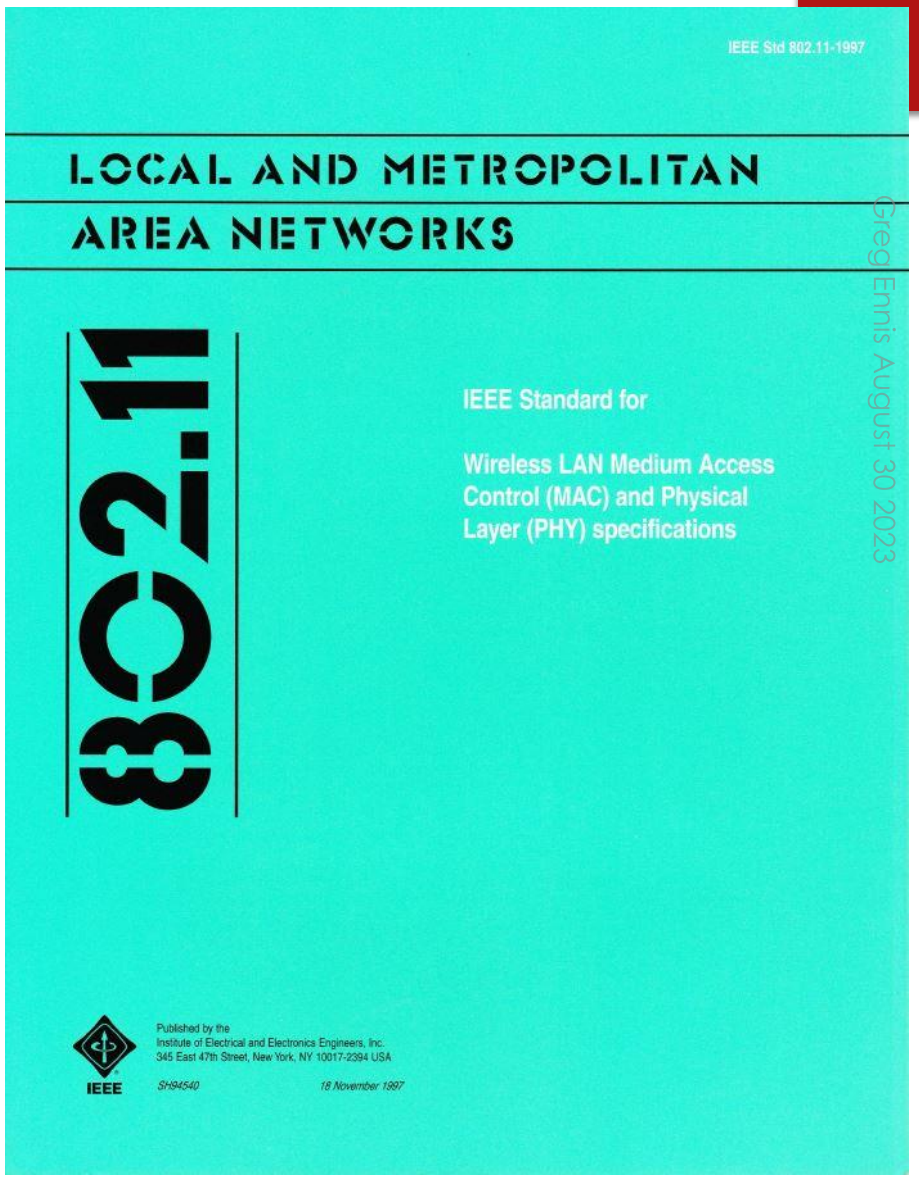
2 megabit direct sequence via Barker code



Original (1997) 802.11 Standard

- MAC based on DFWMAC
- Three PHY layers
- 2 megabit/sec Direct Sequence data rate

- Speed increase was seen as necessary to compete with Ethernet



1998: Competition for “Wireless Ethernet” -- Task Group b

- Holy grail was to achieve 10 megabits, while still being approvable by FCC
- IEEE 802.11 TGb proposals: Micrilor, Harris, Lucent
- Harris and Lucent were backwards compatible with 2 megabit standard – Micrilor was not

Founded 1979 by Bob Metcalfe and others

Focused, not surprisingly, on Ethernet

What's not so well known is their role in the Wi-Fi story

From the Ether / Bob Metcalfe

Wireless computing will flop — permanently

Study the photos in computer publications, including this newspaper right now, and you will notice that almost all of the wires are missing. I'll wait while you look.

Hardly any wires, right? So does this

Bob Metcalfe was not a fan of wireless LANs

less mobile computing have already been realized? Does this mean that, untethered at last, we all can take up the carefree wireless mobile lives of neo-nomads? Answers: No, No, and No.

Furthermore, it is my sad duty to inform you that the coming resounding flop in wireless mobile computing will be, alas, permanent.

There is, I know, an exciting trend toward wirelessness. The relentless progression of smaller, faster, higher capacity, and lower priced computers cries out, "Wires have to go!"

Power cords have to go, replaced by longer-lasting batteries made from sealed lead, nickel cadmium, lithium ion, or maybe plutonium cyclamates (just kidding). And, by the way, let's have a few battery standards so we can share them with our seatmates on planes.

Next, network cables have to go, replaced by higher frequency electromagnetics made from gallium arsenide, spread spectrum, frequency hopping, and packet cellular. And they, too, better work on planes.

Cutting all these cords and cables is exciting, but it isn't inevitable. The truth about wireless computing is that it's not going to pan out.

Simply put, there aren't enough megahertz to go around out there in our increasingly polluted electromagnetic ether. It is an ecologically unsound waste of energy to broadcast bits in all directions when they need to be received in only one. The ether is too scarce to be wasted on nonbroadcast communications, and it won't be.

Cellular telephone companies like to brag about carrying up to 19.2Kb per second to and from your delightfully

million multimedia megabits per second?

So after the wireless mobile bubble bursts later this year, we'll get back to stringing fibers. Instead of computing on the road without wires, we will be installing ubiquitous plugs.

After the wireless mobile bubble bursts this year, we will get back to stringing fibers.

This isn't to say there won't be any wireless computing. Wireless mobile computers will eventually be as common as today's pipeless mobile bathrooms. Portapotties are found on planes and boats, at construction sites, rock concerts, and other places where it is very inconvenient to run pipes. But bathrooms are still predominantly plumbed. For more or less the same reasons, computers will stay wired.

Need more reasons why wireless won't become widespread? There are the privacy challenges of wide-area data broadcasting, which you'll encounter as you demonstrate that you care. What about standards for wireless computer networking, which will settle down right after ISDN, HDTV, PCMCIA, and ATM are resolved. Consider governments around the world reallocating spectrum for use by wireless computer

they will right after

opped. And there are

prolonged exposure

s of higher frequency

electromagnetic radiations, which I hope are nil. And finally, what about the vast amounts of money needed for building wireless networking infrastructure, which will be raised right after The Deficit is eliminated?

Of course, many of these issues may be resolved in our lifetimes. So even if I'm wrong about the *permanent* shortage of real ether, wires will be keeping us civilized for a very long time.

Is it any wonder, then, that the TV industry, which has relied on broadcast radio for most of its history, is in a full-swing switch to cable? Increasingly we will switch data via fiber networks instead of broadcasting it via radio.

And in case you're not upset yet, there's this angle: If half the world's problems are caused by having too many people, the other half are caused by all of us wanting to move around so much — from home to work, from work to our customer's work, from our picturesque hometowns to identical airports, hotels, and tourist traps around the world. So let's just wire up our homes and stay there.

InfoWorld publisher Bob Metcalfe invented Ethernet in 1973 and founded 3Com Corp. in 1979. He receives E-mail via the Internet at bob_metcalfe@infoworld.com or at 524-1127 on MCI Mail.

Greg Ennis August 30 2023

From the Ether / Bob Metcalfe

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Hardly any wires, right? So does this mean that the unphotogenic tangle hanging off the back of your desk is a thing of the past? Does this mean that several years of raised hopes about wireless mobile computing have already been realized? Does this mean that, untethered at last, we all can take up the carefree wireless mobile lives of neonomads? Answers: No, No, and No.

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Cellular telephone companies like to brag about carrying up to 19.2Kb per second to and from your delightfully wireless mobile computer. Excuse me, but aren't you finding that 10Mb per second is a little on the slow side; maybe you're going to need ATM at several million multimedia megabits per second?

So after the wireless mobile bubble bursts later this year, we'll get back to stringing fibers. Instead of computing on the road without wires, we will be installing ubiquitous plugs.

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This isn't to say there won't be any wireless computing. Wireless mobile computers will eventually be as common as today's pipeless mobile bathrooms. Portapotties are found on planes and boats, at construction sites, rock concerts, and other places where it is very inconvenient to run pipes. But bathrooms are still predominantly plumbed. For more or less the same reasons, computers will stay wired.

Need more reasons why wireless won't become widespread? There are the privacy challenges of wide-area data broadcasting, which you'll encounter as you demonstrate that you care. What about standards for wireless computer networking, which will settle down right after ISDN, HDTV, PCMCIA, and ATM are resolved. Consider governments around the world reallocating spectrum for use by wireless computer networks, which they will right after whale hunting is stopped. And there are the health risks of prolonged exposure to increasing levels of higher frequency electromagnetic radiations, which I hope are nil. And finally, what about the vast amounts of money needed for building wireless networking infrastructure, which will be raised right after The Deficit is eliminated?

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“This isn’t to say there won’t be any wireless computing. Wireless mobile computers will eventually be as common as today’s pipeless mobile bathrooms. Porta-potties are found on planes and boats, on construction sites, at rock concerts, and other places where it is very inconvenient to run pipes. But bathrooms are still predominantly plumbed. For more or less the same reasons, computers will stay wired”.

Bob Metcalfe, August 16, 1993

Greg Ennis August 30 2023

1998: 3Com's Wireless LAN Initiative

But by 1998, Metcalfe was not involved in 3Com's management, and 3Com plays a major role in the Wi-Fi story

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1998: 3Com's Wireless LAN Initiative

Symbol Technologies to develop a family of high-speed wireless LAN products …

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1998: 3Com's Wireless LAN Initiative

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using source technology incorporated in a chip from Harris …

1998: 3Com's Wireless LAN Initiative

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to be marketed under the 3Com brand and sold through 3Com's distribution.

“Trilogy”

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This was the beginning of what was to become the Wi-Fi Alliance

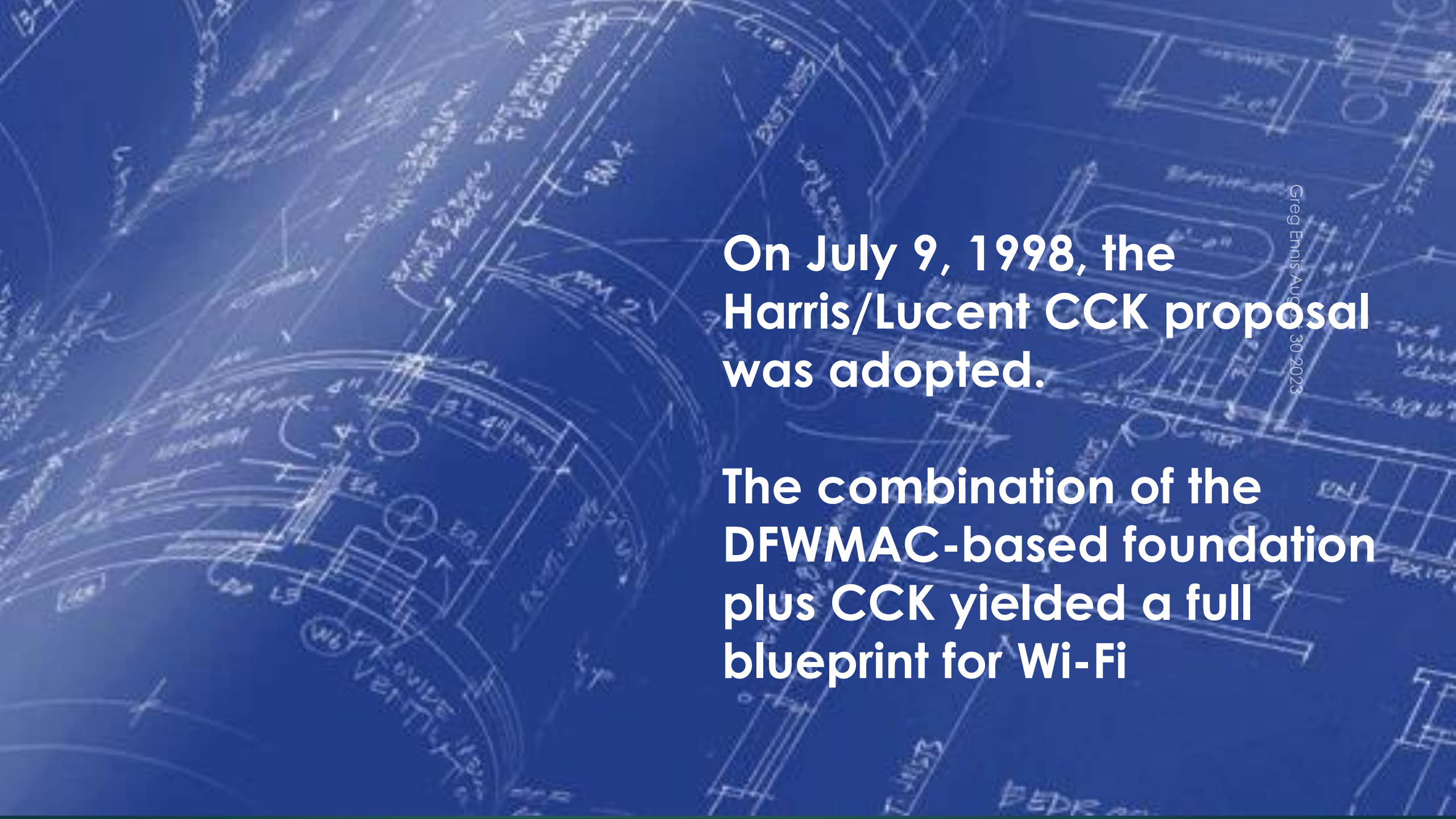
Competition for “Wireless Ethernet”: Task Group b

- Holy grail was to achieve 10 megabits, while still being approvable by FCC
- IEEE 802.11 TGb proposals: Micrilor, Harris, Lucent
- Harris and Lucent were backwards compatible with 2 megabit standard – Micrilor was not

But a parliamentary procedure objection during the IEEE deliberations was to have an impact on the story.

Competition for "Wireless Ethernet": Task Group b

- Micrilor was on the cusp of winning when an accusation of voting irregularities was brought forward
- Process was restarted – Harris and Lucent subsequently developed a merged proposal called "Complementary Code Keying"
- 11 megabits/sec direct sequence



On July 9, 1998, the Harris/Lucent CCK proposal was adopted.

The combination of the DFWMAC-based foundation plus CCK yielded a full blueprint for Wi-Fi

At this same time, an organization was formed promoting an alternative wireless LAN approach.

Wireless LAN consortium founded in 1998, focused on home market

Proxim, Intel, Siemens, Motorola, IBM, Microsoft, …

1.6 megabit/sec frequency hopping

Competitive with IEEE 802.11

In late 1998 and early 1999, the Trilogy team tried and failed to convince HomeRF to adopt 802.11b as the multimedia enhancement to HomeRF

This led to the decision to form a consortium similar to HomeRF but focused on 802.11b

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Symbol, Harris, and 3Com invited Lucent, Aironet, and Nokia to join with the Trilogy team to form WECA

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Wireless Ethernet Compatibility Alliance

Wireless Ethernet Compatibility Alliance

3Com More connected.

Aironet

HARRIS Semiconductor

"Soon to be Intersil"

Wireless Ethernet Compatibility Alliance

This slide is from the very first analyst briefing by WECA

Analyst Briefing
August, 1999

Lucent Technologies
Bell Labs Innovations

NOKIA
CONNECTING PEOPLE

symbol

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Interbrand was hired to come up with a name and logo to replace "IEEE 802.11b High Rate Wireless LAN"

Possibilities that they offered included TorchLight, Trapeze, and DragonFly

Something like this might have become the new brand identity for 802.11b

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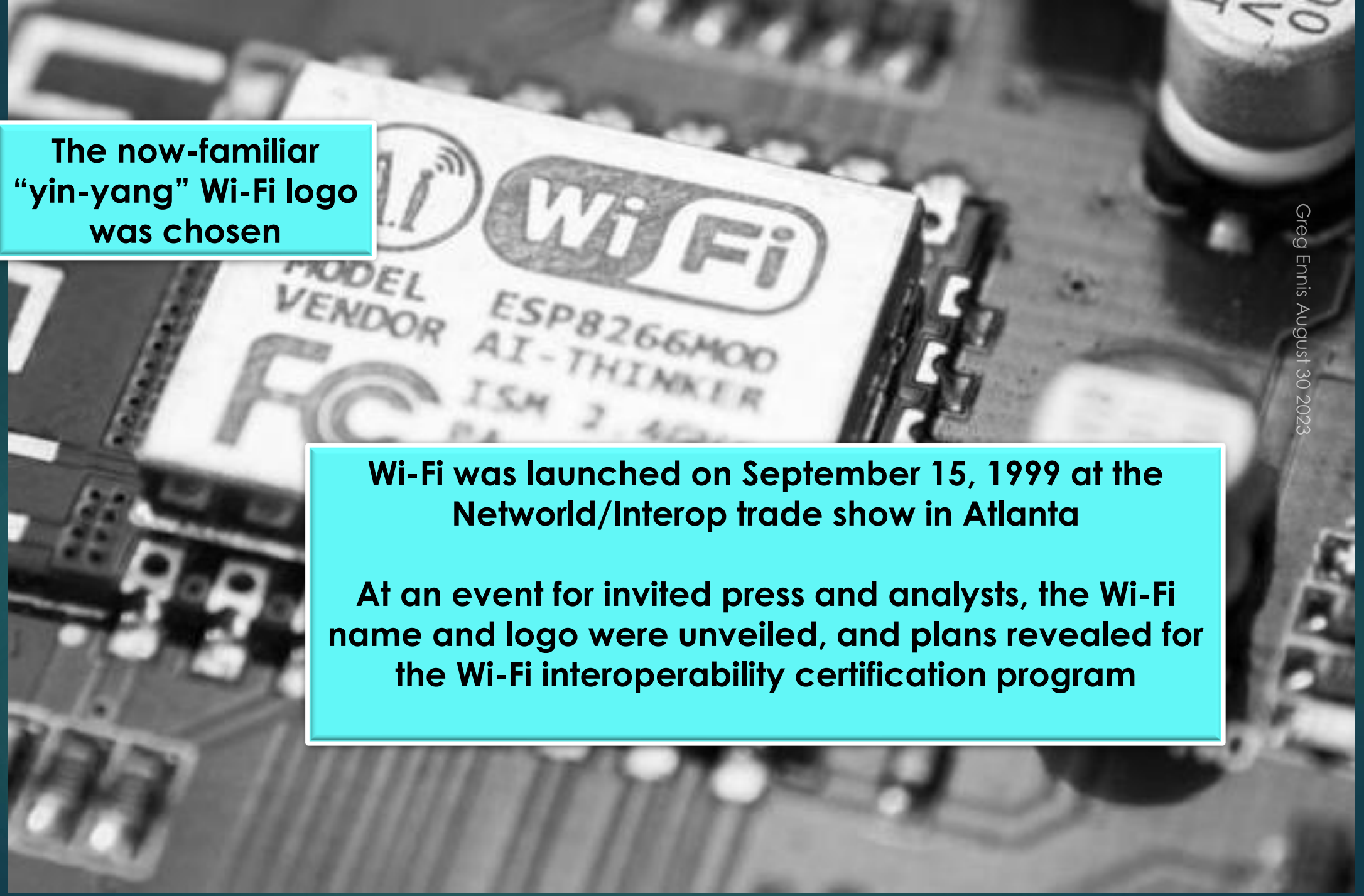
Once the name Wi-Fi was picked, Interbrand proposed various graphic logos

Which identity best visualizes our objectives?

Wireless Speed Communication



The now-familiar "yin-yang" Wi-Fi logo was chosen

Wi-Fi was launched on September 15, 1999 at the Networld/Interop trade show in Atlanta

At an event for invited press and analysts, the Wi-Fi name and logo were unveiled, and plans revealed for the Wi-Fi interoperability certification program

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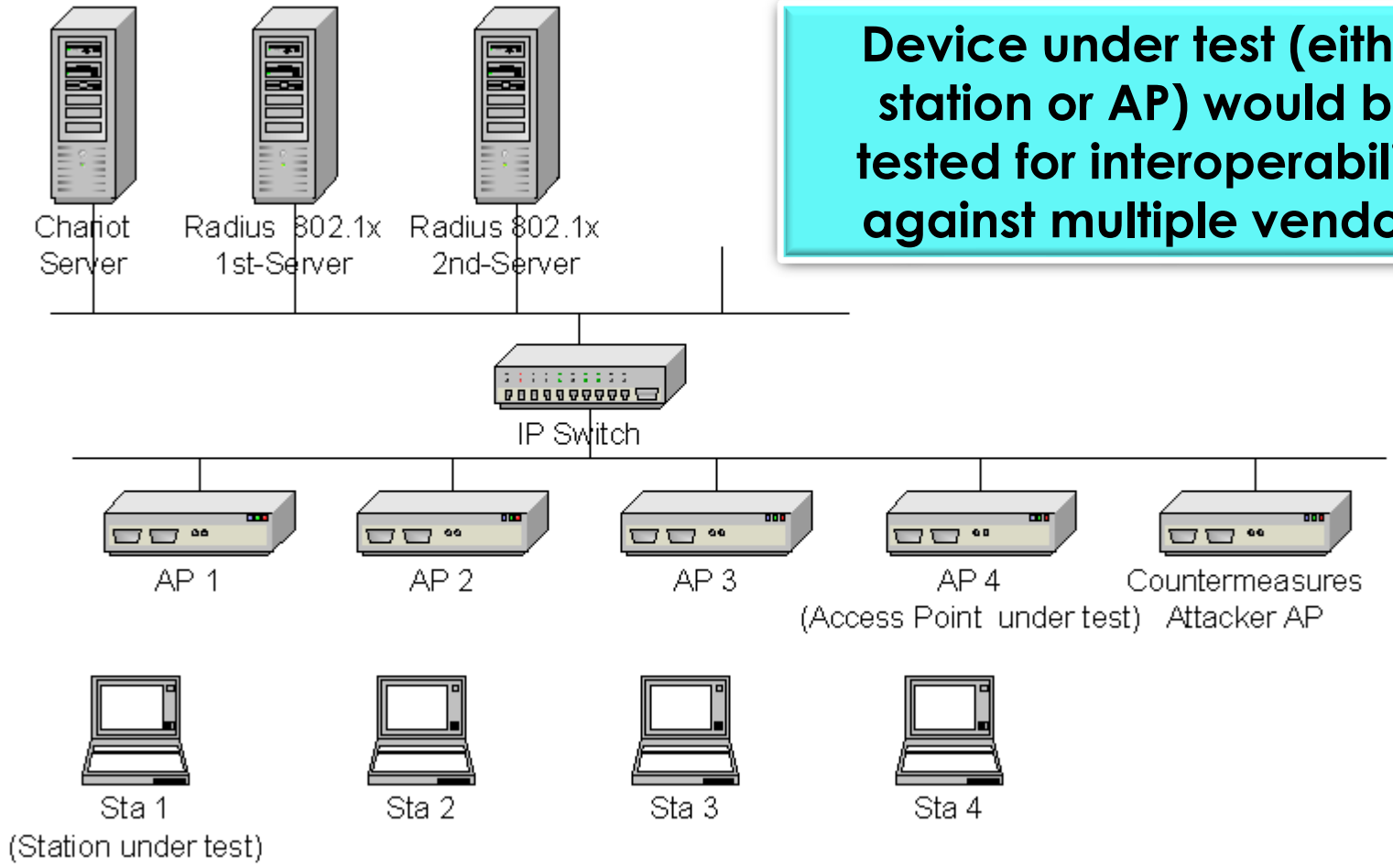
WECA would subsequently rename itself the Wi-Fi Alliance

Interoperability Certification



Device under test (either station or AP) would be tested for interoperability against multiple vendors

Figure taken from an early Wi-Fi Alliance Certification Test Plan

Over 60,000 products have now achieved Wi-Fi certification

HomeRF attempted to get the FCC to approve a higher speed version of Frequency Hopping ("Wideband FH") to compete with 802.11b

This approval did not arrive in time to stem the growing popularity of 802.11b

HomeRF proponents abandoned the organization, moved over to join the Wi-Fi Alliance, and HomeRF was dissolved

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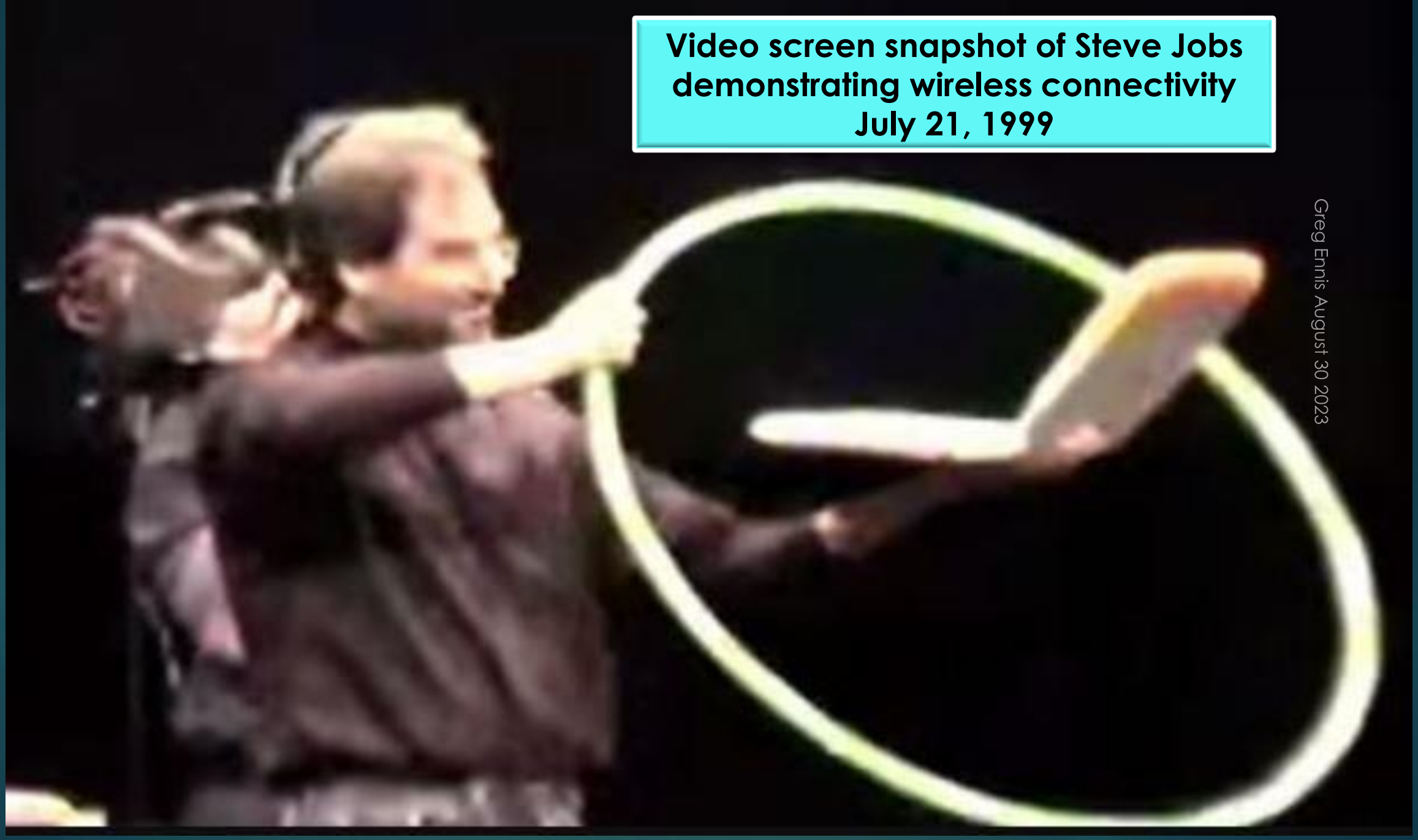
Wi-Fi Alliance today has over 800 Member Companies

Wi-Fi Alliance Sponsor Companies 2023

- Apple
- Broadcom Corporation
- Cisco Systems
- Comcast
- Dell Technologies
- Huawei Technologies Co., Ltd.
- Intel
- LG Electronics
- Nokia Corporation
- NXP Semiconductors
- Qualcomm
- Samsung Electronics
- Sony Group Corporation
- Texas Instruments



Video screen snapshot of Steve Jobs demonstrating wireless connectivity July 21, 1999

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Significance of Apple/Lucent deal

- Choice of IEEE 802.11 rather than HomeRF or Proxim
- $99 price point was a major step, and would have to be matched by competitors
- The "Airport" branding – not calling it Wi-Fi – was potentially an impediment to the successful launch of the Wi-Fi name
- Would Apple tweak this into an Apple-specific version of 802.11?
- The answer came back just seven weeks later: Apple joined WECA, with a commitment to Wi-Fi certify their products

April 17, 2000 – First Wi-Fi Certs

Press Release:

“The Wireless Ethernet Compatibility Alliance (WECA) announced today that it has awarded the first Wi-Fi certifications for wireless LAN product interoperability”.

Testbed incorporated products from Symbol, Lucent, Aironet, and 3Com

April 17, 2000 – First Wi-Fi Certs

Sixteen products from eight different manufacturers, nine PC cards, seven access points, all interoperable.

Early example of a Wi-Fi certified laptop adapter card

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Crisis

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January 29, 2001

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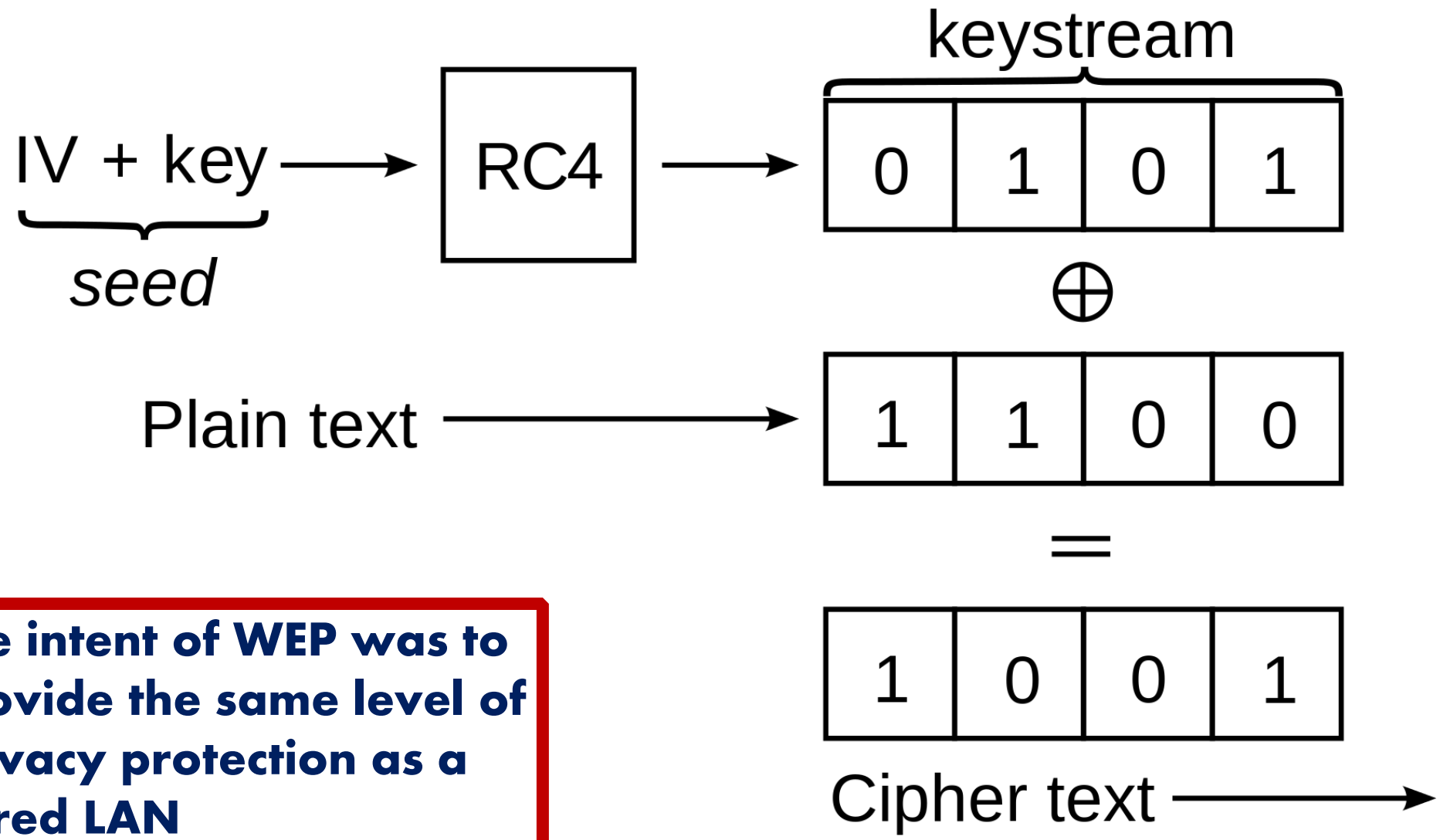
Analysis of 802.11 Security or *Wired Equivalent Privacy* ***Isn't***

Nikita Borisov, Ian Goldberg, and David Wagner

Title slide from presentation announcing the breaking of Wi-Fi's original encryption scheme

WEP

- “Wired Equivalent Privacy” was the name for the original 1997 encryption scheme in the 802.11 specification
- The cryptic naming (forgive the pun) stemmed from its goal: to provide the same level of privacy protection as Ethernet
- Note that Ethernet had no encryption – its privacy protection depended on the fact that it was wired and hence hard to tap into



The intent of WEP was to provide the same level of privacy protection as a wired LAN

Cracked!

Borisov, Goldberg, and Wagner had demonstrated that WEP was susceptible to attacks (man-in-the-middle and others)

Presented at "The Second Millennium Mac Crypto-Conference on Macintosh Cryptography and Internet Commerce" in January 2001.

IEEE 802.11 was working on an enhancement: not ready for over a year

Cracked!

This ended up having a more significant impact on the future of Wi-Fi than you might think

+

IEEE 802.11 and Wi-Fi Alliance decided to collaborate on the solution

Portions of 802.11's WEP enhancement were designated, and the Wi-Fi Alliance developed a certification program called "Wi-Fi Protected Access"

IEEE + Wi Fi ALLIANCE

The WPA certification program was launched before the ratification of the IEEE standard

IEEE + Wi Fi ALLIANCE

This was the prototype of a working relationship between the two organizations that has resulted in 18 billion devices around the globe

Some topics not addressed today

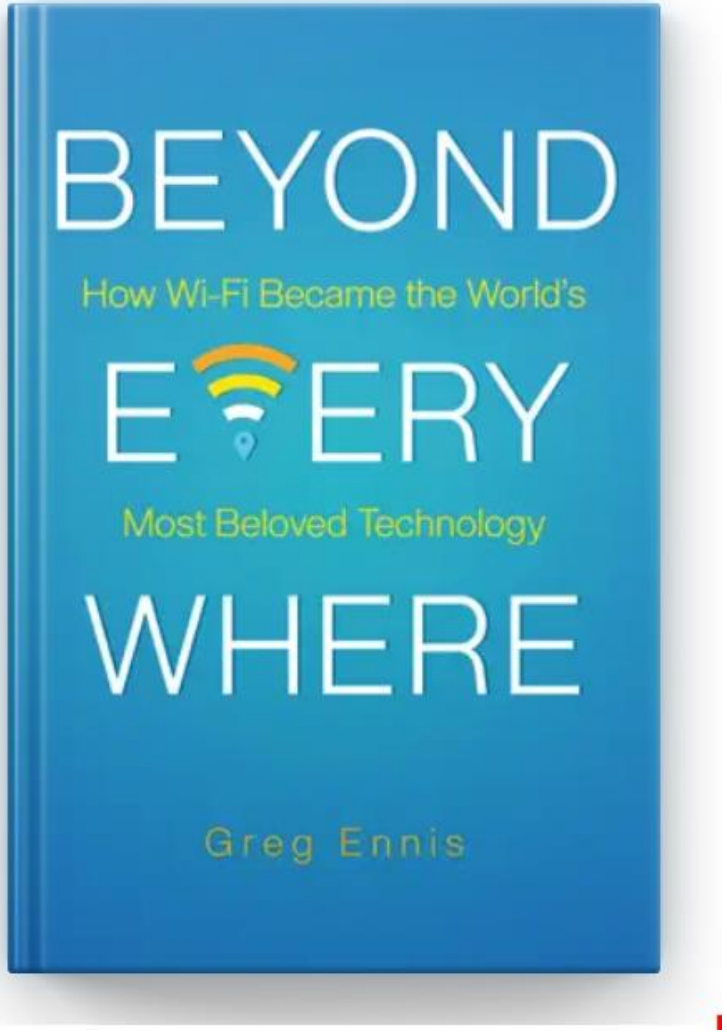
Internet of Things

China's attempt to replace Wi-Fi with a national technology

Drama of putting Wi-Fi into cellphones

Why Netflix is an entertainment behemoth today (hint: Wi-Fi Smart TVs)

These topics (and others) are all in the book



PAST

PRESENT

FUTURE

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Wi-Fi Generations

Wi-Fi generations V · T · E

Generation	IEEE standard	First Approved	Maximum link rate (Mbit/s)	Radio frequency (GHz)		
Wi-Fi 7	802.11be	2019-03-21	1376 to 46120	2.4	5	6
Wi-Fi 6/6E	802.11ax	2014-03-27	574 to 9608	2.4	5	6[3]
Wi-Fi 5	802.11ac	2008-09-26	433 to 6933	↓[4]	5	
Wi-Fi 4	802.11n	2003-09-11	72 to 600	2.4	5	
(*Wi-Fi 3*)*	802.11g	2000-09-21	6 to 54	2.4		
(*Wi-Fi 2*)*	802.11a	1997-09-16			5	
(*Wi-Fi 1*)*	802.11b	1997-12-09	1 to 11	2.4		
(*Wi-Fi 0*)*	802.11	1991-03-21	1 to 2	2.4		

Wi-Fi Generations

Point Number One:
Don't trust Wikipedia

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Point Number Two:
Increasing Speeds

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Wi-Fi Generations

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Increasing Capacity

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Wi-Fi Generations

Point Number Three:
Increasing Bandwidth

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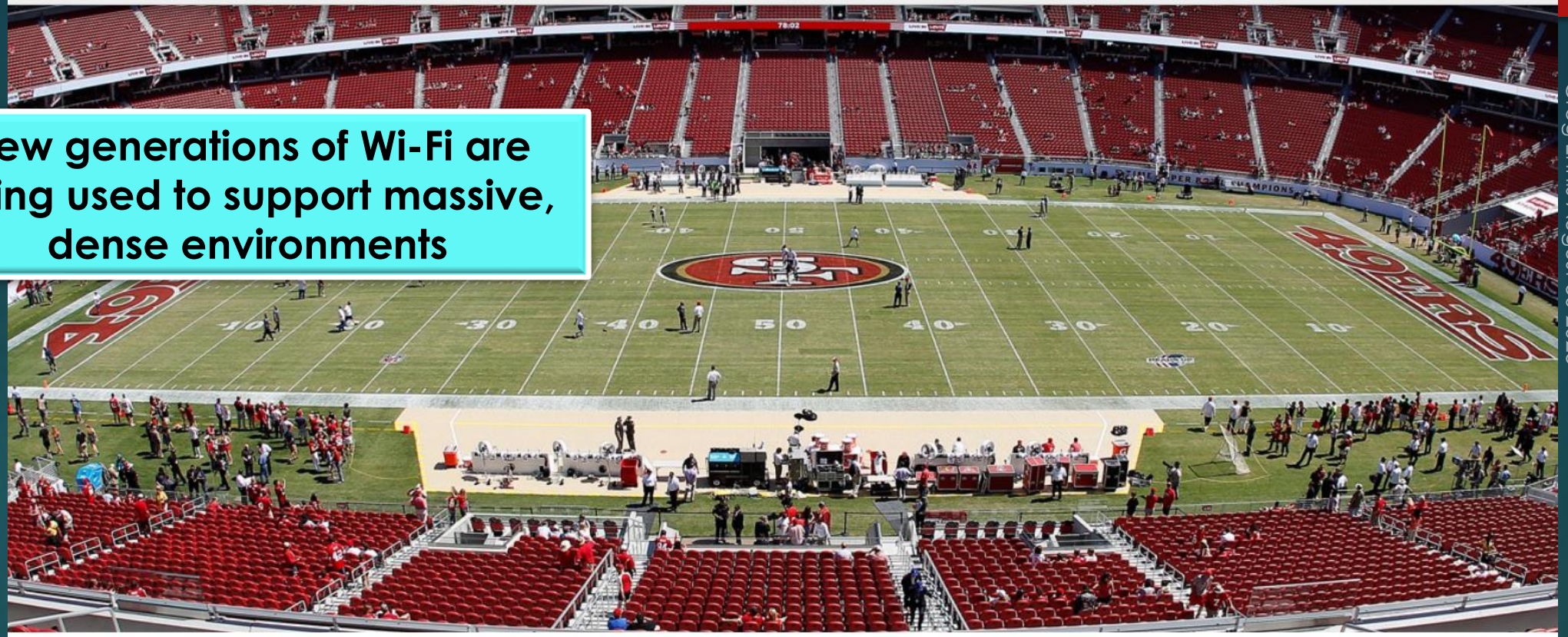
levisstadium.com/2014/09/progress-tk-interesting-facts-levis-stadium-wifi-mobile-app-ninerds/

LEVI'S® STADIUM

EXPERIENCE TICKETS SUITES EVENTS GETTING HERE GUEST SERVICES

New generations of Wi-Fi are being used to support massive, dense environments

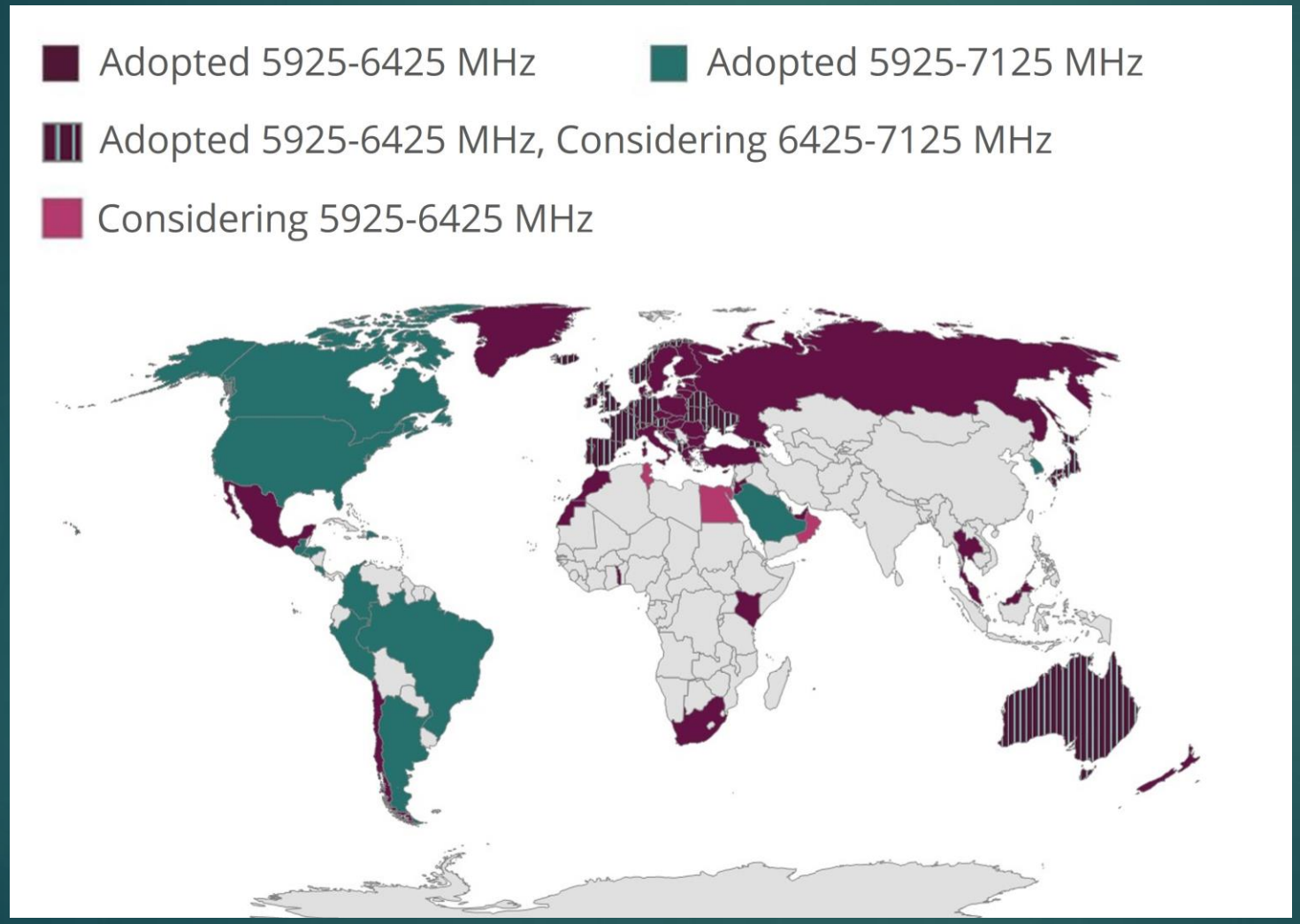


SEP 08

INTERESTING FACTS ABOUT LEVI'S® STADIUM WIFI, MOBILE APP AND NINERDS

Greg Ennis August 30 2023

Increasing Availability of 6GHz



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6GHz band will also be available here
NATIONAL GEOGRAPHIC
COLONIZING
MARS
Could humans live on Mars? One day, perhaps. But establishing settlements there would be a forbidding task. The vision shown here is drawn from the National Geographic Channel's global event series on Mars. It reflects what some scientists are thinking right now, based on the most recent research. Time will tell if it's a blueprint for living on the red planet.
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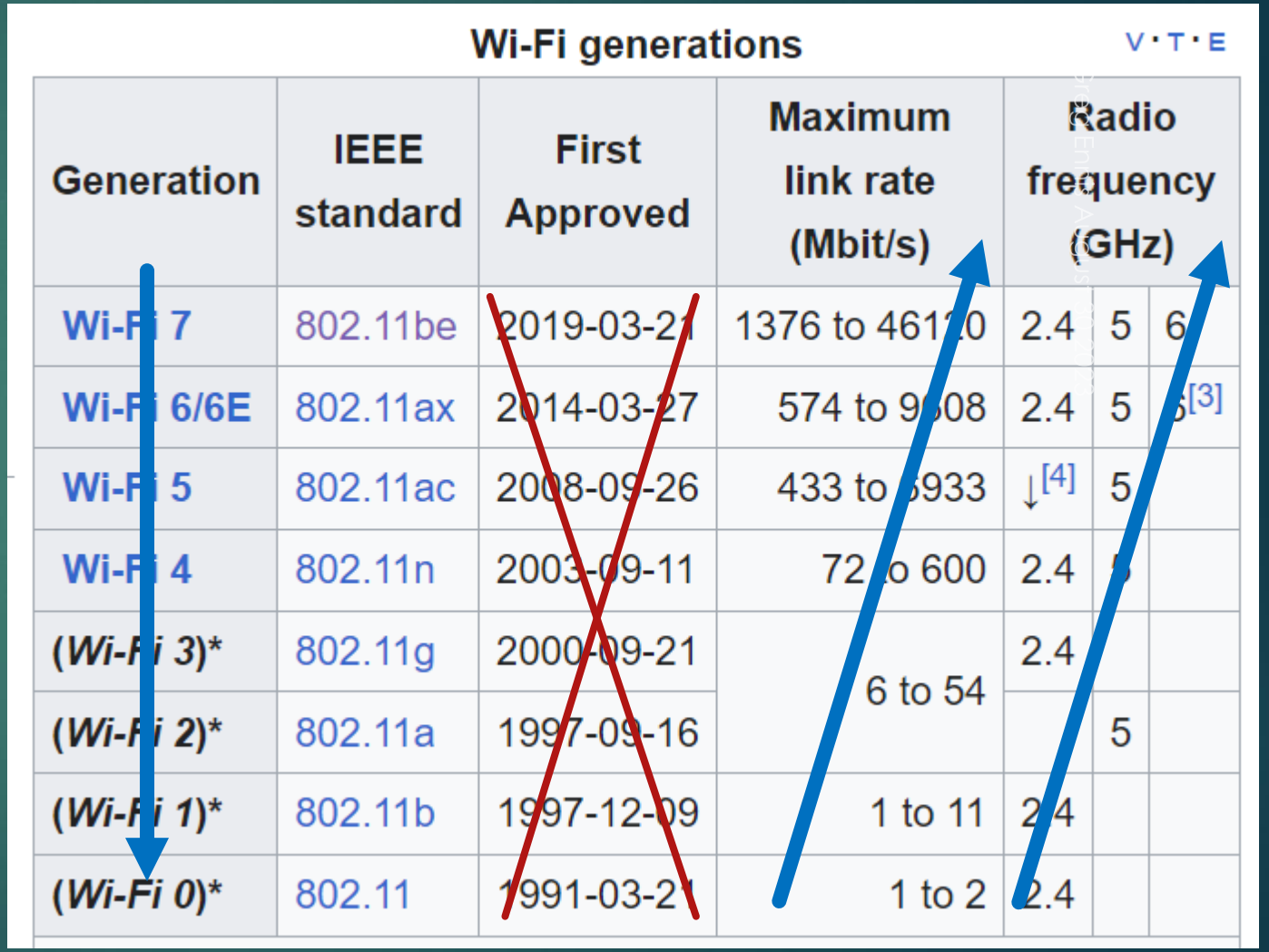
The Challenge of an Unforgiving World
A key step in the journey to Mars is to orbit it, which NASA hopes will happen in the 2030s. But landing, surviving, and ultimately thriving on the red planet – with its low gravity level, seesawing temperatures, and nearly oxygen-free atmosphere – present myriad issues for human colonists.
Solutions for Survival
The more resources we can find – or create – to make Mars habitable, the fewer we'd have to bring from Earth. Scientists are now studying ways to use what already exists on Mars. To establish a colony, humans would need to be able to supply five things: oxygen, water, shelter, food, and energy.
FUEL
METHANE GENERATION
WATER
EXTRACTING WATER FROM AIR
ENERGY
POWER FROM THE SUN
ENERGY
PORTABLE POWER
ENERGY
NUCLEAR POWER
WATER
GETTING GROUNDWATER
OXYGEN
BETTER BREATHING THROUGH CHEMISTRY
FOOD
MARTIAN GREENHOUSES
Crops grown in soil simulants
Percentage alive after 50 days
SHELTER
LIVING IN LAVA TUBES
WATER
HIDDEN GLACIERS
COMMUNICATION
MARS
To learn more about colonizing the red planet, tune in to the Channel's global event series, MARS, on November 14 at 9/8c.
For related educational resources go to natgeoed.org/mars

Wi-Fi Generations

Point Number Four:
Backwards
Interoperability



Wi-Fi generations V · T · E

Generation	IEEE standard	First Approved	Maximum link rate (Mbit/s)	Radio frequency (GHz)		
Wi-Fi 7	802.11be	2019-03-21	1376 to 46120	2.4	5	6
Wi-Fi 6/6E	802.11ax	2014-03-27	574 to 9608	2.4	5	6[3]
Wi-Fi 5	802.11ac	2008-09-26	433 to 6933	↓[4]	5	
Wi-Fi 4	802.11n	2003-09-11	72 to 600	2.4	5	
(*Wi-Fi 3*)*	802.11g	2000-09-21	6 to 54	2.4		
(*Wi-Fi 2*)*	802.11a	1997-09-16			5	
(*Wi-Fi 1*)*	802.11b	1997-12-09	1 to 11	2.4		
(*Wi-Fi 0*)*	802.11	1991-03-21	1 to 2	2.4		

Already working on Wi-Fi 8

- IEEE 802.11bn
- 10 gigabits

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Metcalfe's Law

The value of a network is proportional to the square of the number of interconnected devices

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18 Billion Squared

324,000,000,000,000,000,000

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18 Billion Squared

324,000,000,000,000,000,000

Product developers will continue to see Wi-Fi as the most attractive connectivity option

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Thank You!

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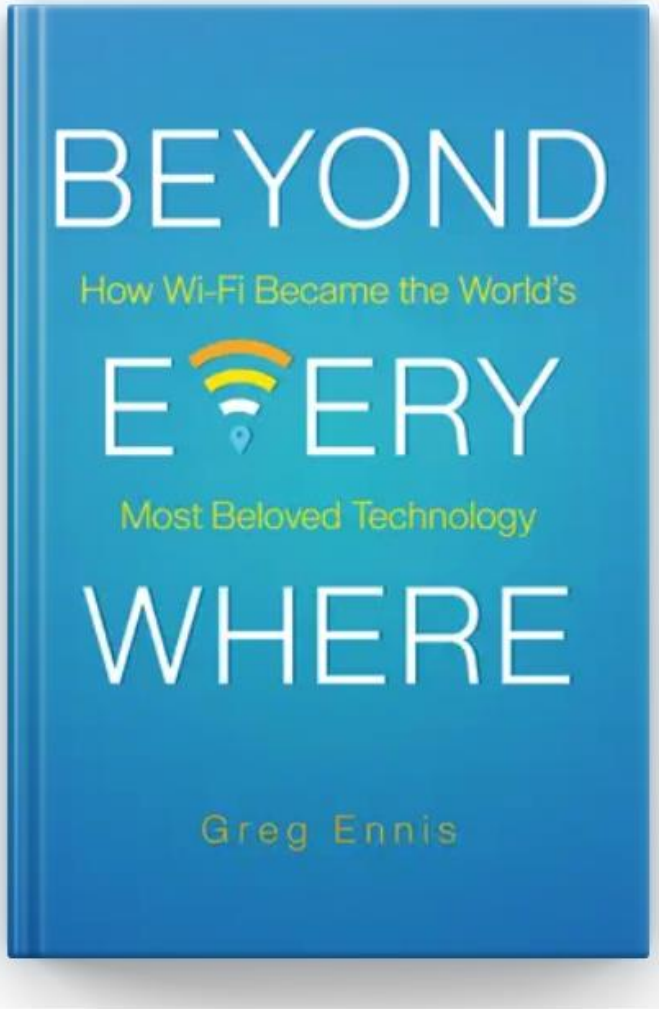
www.gregennis.net



The material in this presentation is drawn from my book

Beyond Everywhere
How Wi-Fi Became the World's Most Beloved Technology

By Greg Ennis

from Post Hill Press

available at amazon.com

//amzn.to/3XZYQXS

and at BARNES&NOBLE

//bit.ly/3sELmoZ