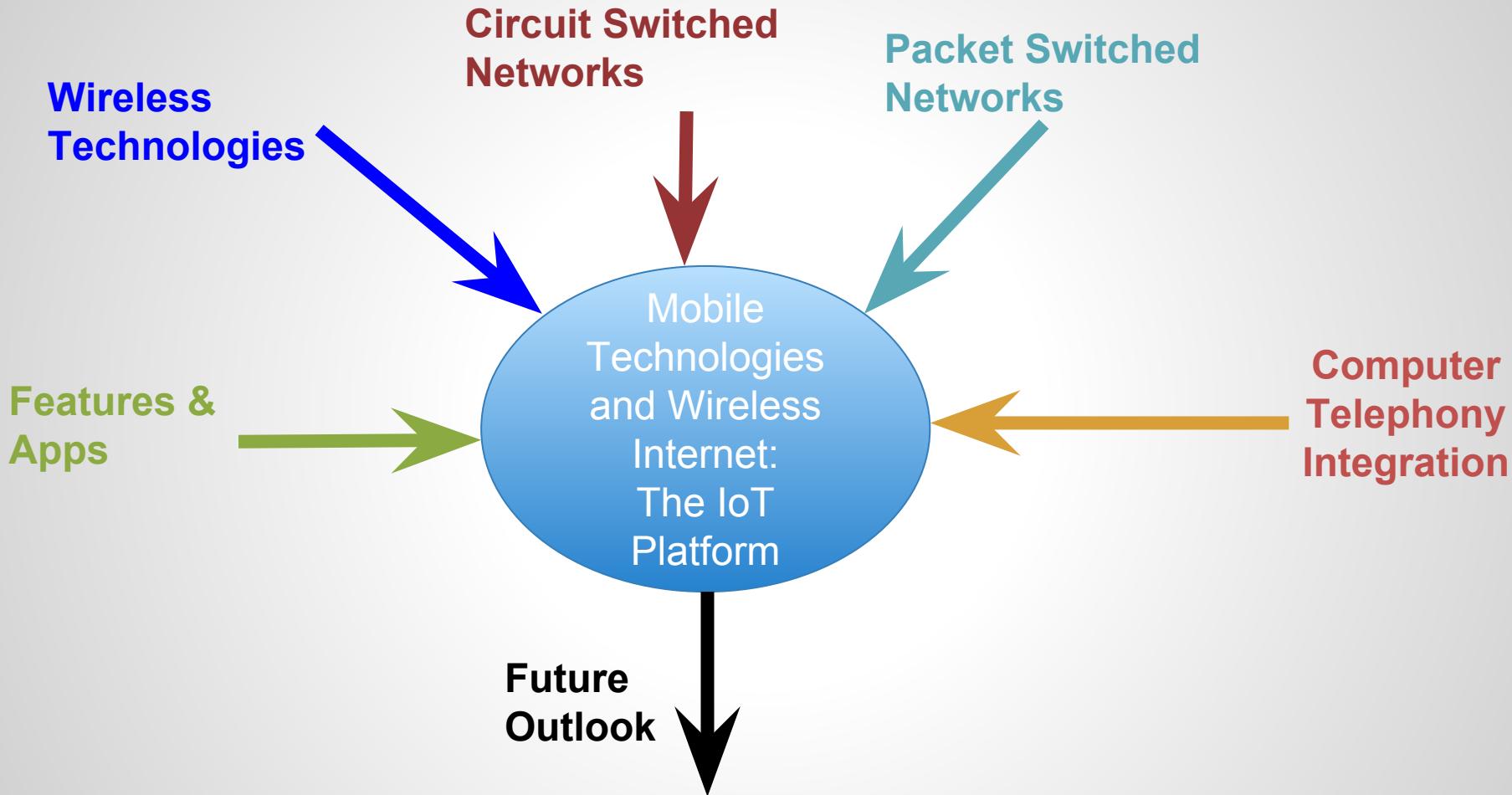


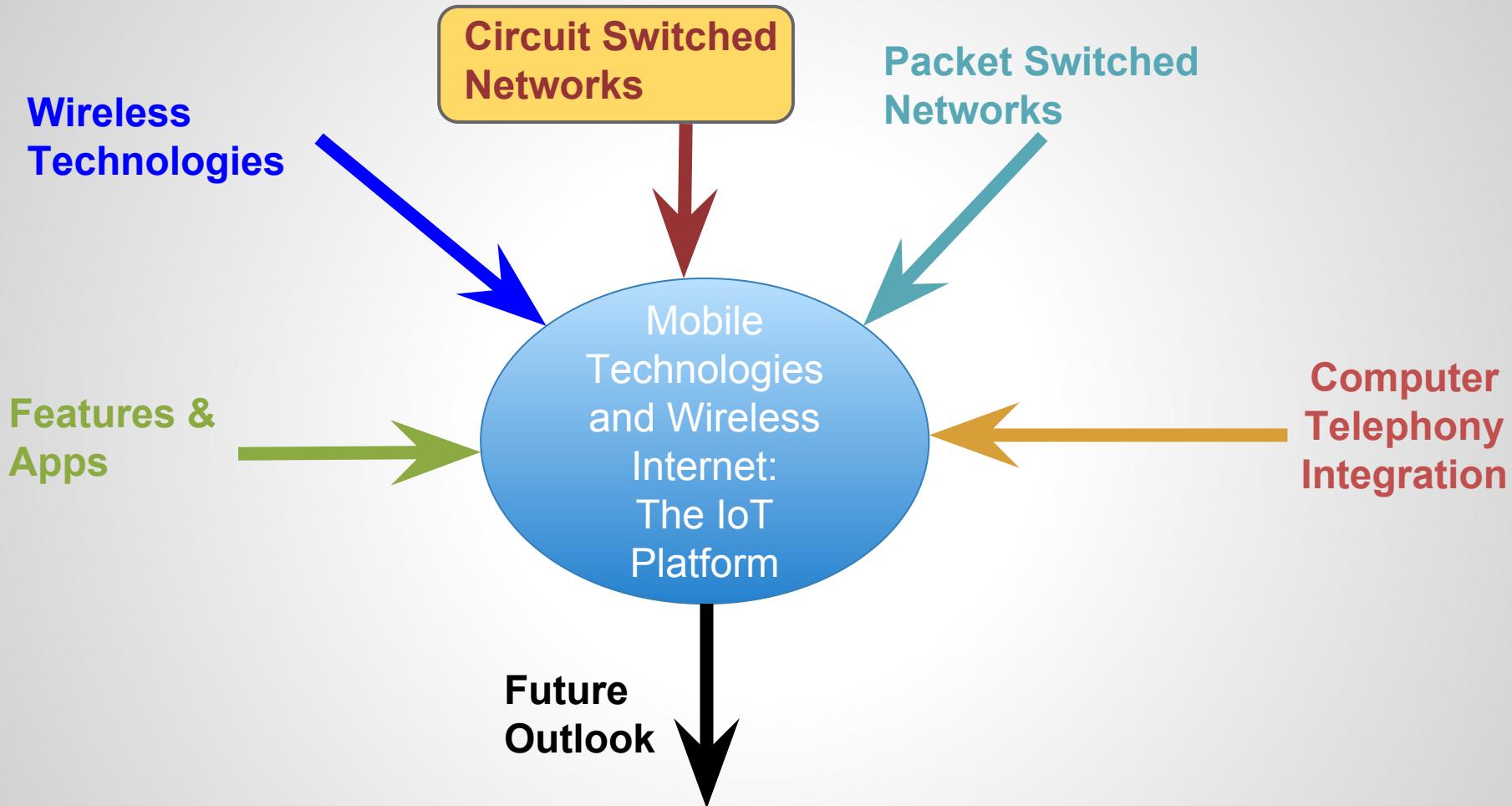
# Internet of Things: Circuit Switched Networks

---

Harinath Garudadri and Ganz Chockalingam

Qualcomm Institute of Calit2  
University of California, San Diego





# **Lesson 1**

Telephony Network

# Lesson 1 | Telephony Network

1 - We love to talk



2 - Birth of the Telephone



3 - Control Plane



4 - Data Plane

1 – We love to talk

We all love to talk.  
Language is unique to us Humans!



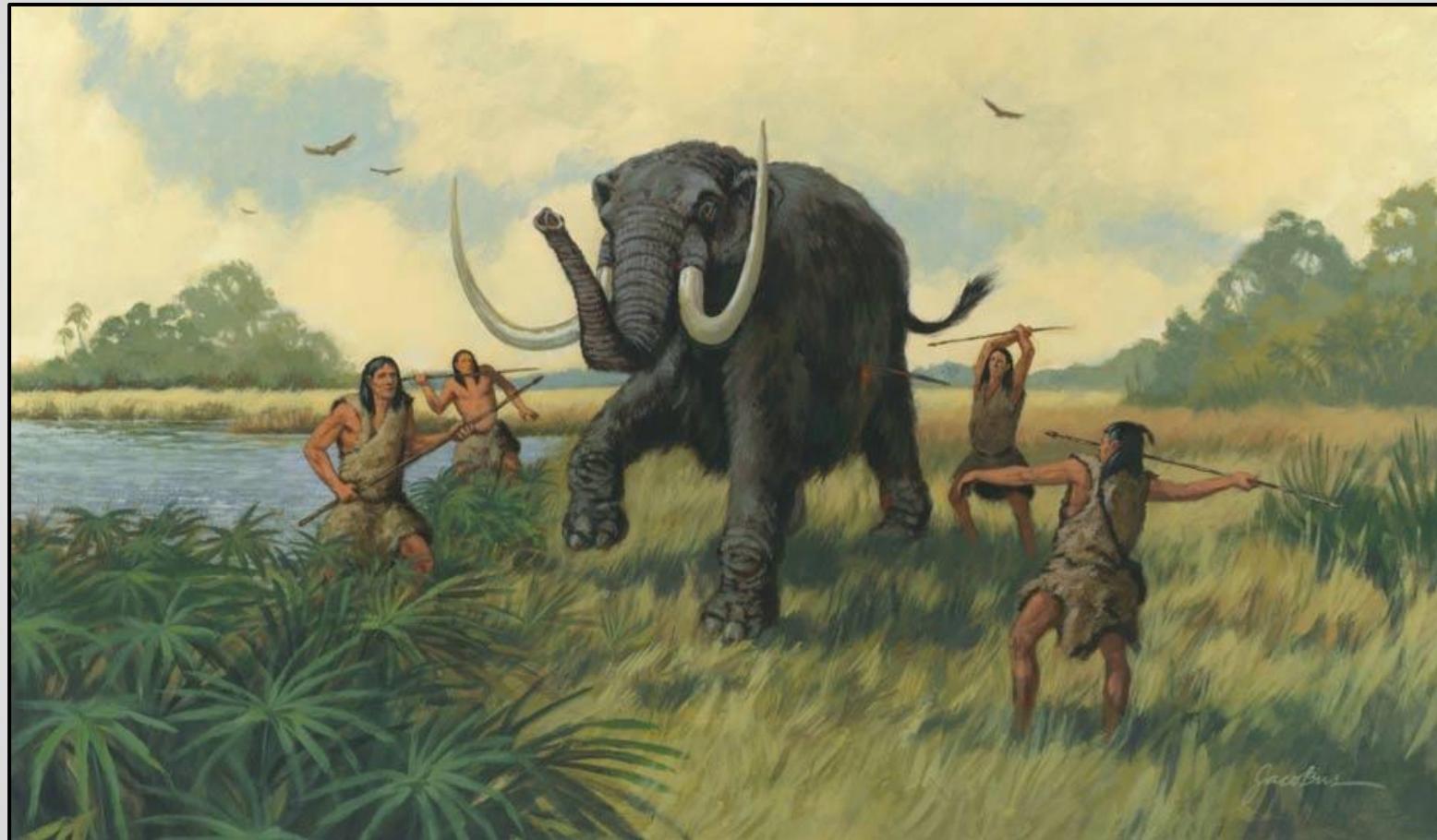
## What is Language?

---

Language is a system of communicating. Many animal and even plant species communicate with each other. Humans are not unique in this capability. However, human language is unique in being a symbolic communication system that is learned instead of biologically inherited.

Language shapes our thoughts and embodies different ways of knowing the world.

# 1 | We love to talk



# He Gave the World the Printed Page



## J Around 1454

Johannes Gutenberg was a determined young man. When he faced a problem, he never gave up. Instead, he looked for a solution--and usually he found it.

After he finished school, Johannes went to work with his father at the local mint. The mint was where coins were made. One day Johannes had an idea. "Coins are made by stamping metal," he thought. "What if I use some kind of stamp to make books, too?"

Johannes set to work. In his shop, he started to make tiny letters of the alphabet out of a metal called lead. These metal letters were called movable type.

Johannes arranged the letters into words, sentences, and whole pages. Then he smeared ink on the letters, took a sheet of paper, and pressed it against the letters with his hands. He had a printed page!

# 1 | We love to talk

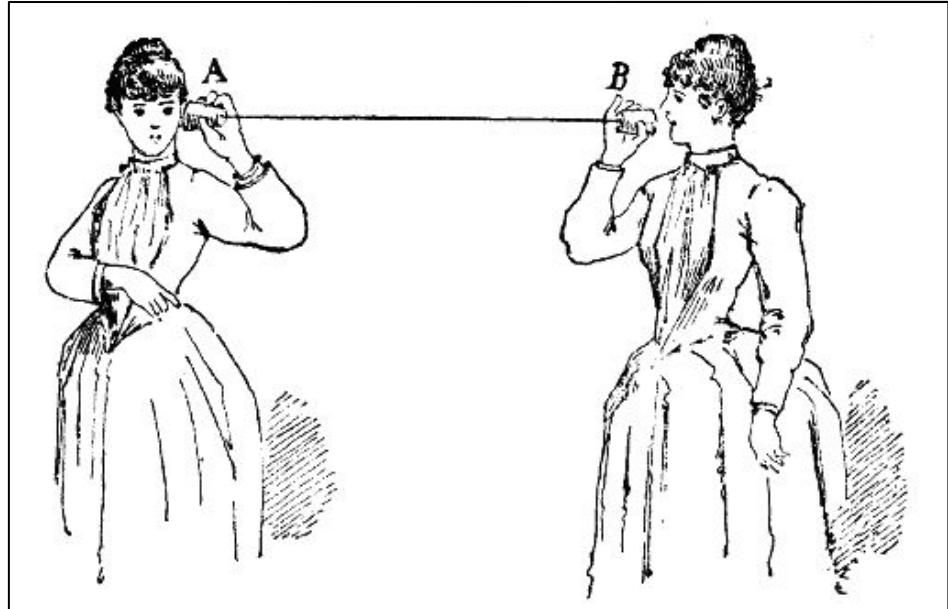


1 | We love to talk

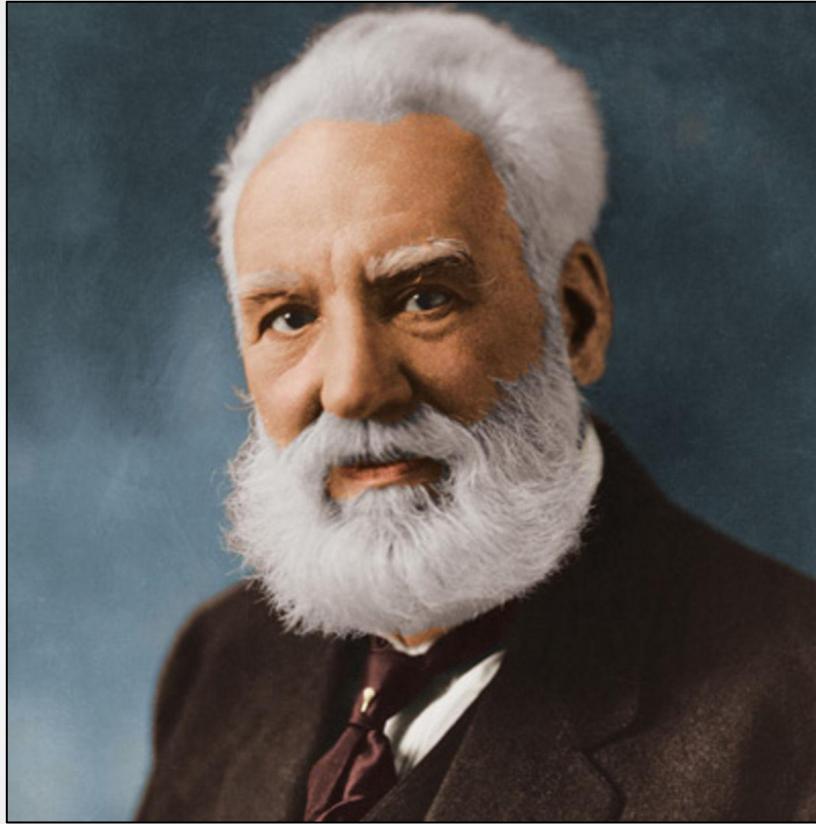


## 2 – Birth of the Telephone

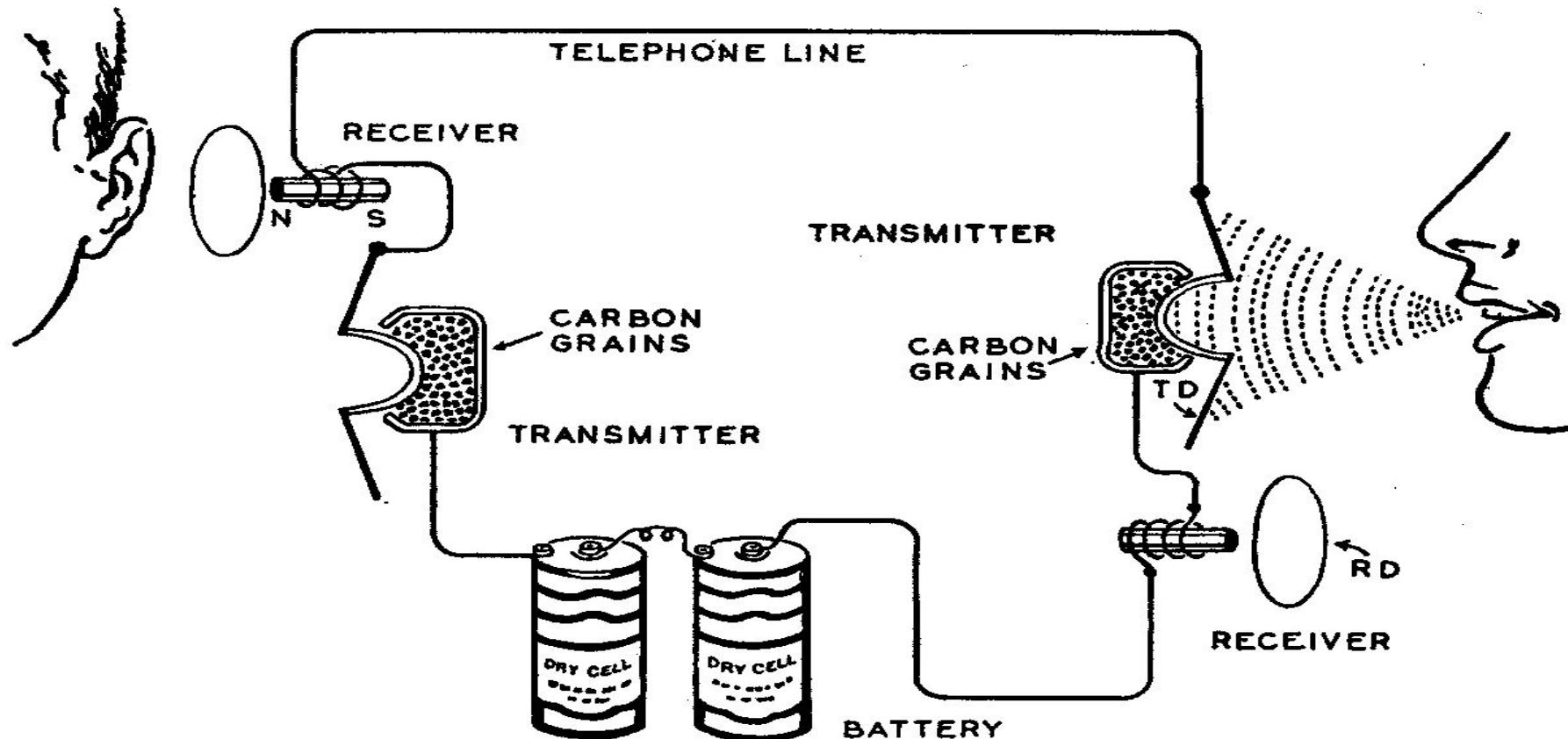
## 2 | Birth of the Telephone



## 2 | Birth of the Telephone



## 2 | Birth of the Telephone

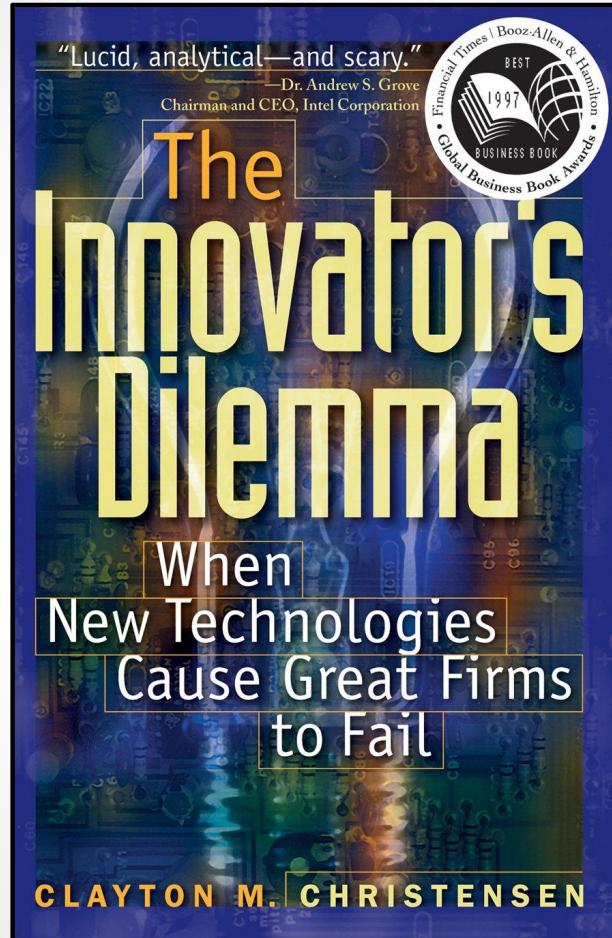


## 2 | Birth of the Telephone

*“There are conditions in America which necessitate the use of such instruments more than here. Here we have a superabundance of messengers, errand boys and things of that kind ... The absence of servants has compelled America to adopt communications systems for domestic purposes”*

-- *Sir William Preece,  
Chief Engineer, British Post Office*

## 2 | Birth of the Telephone

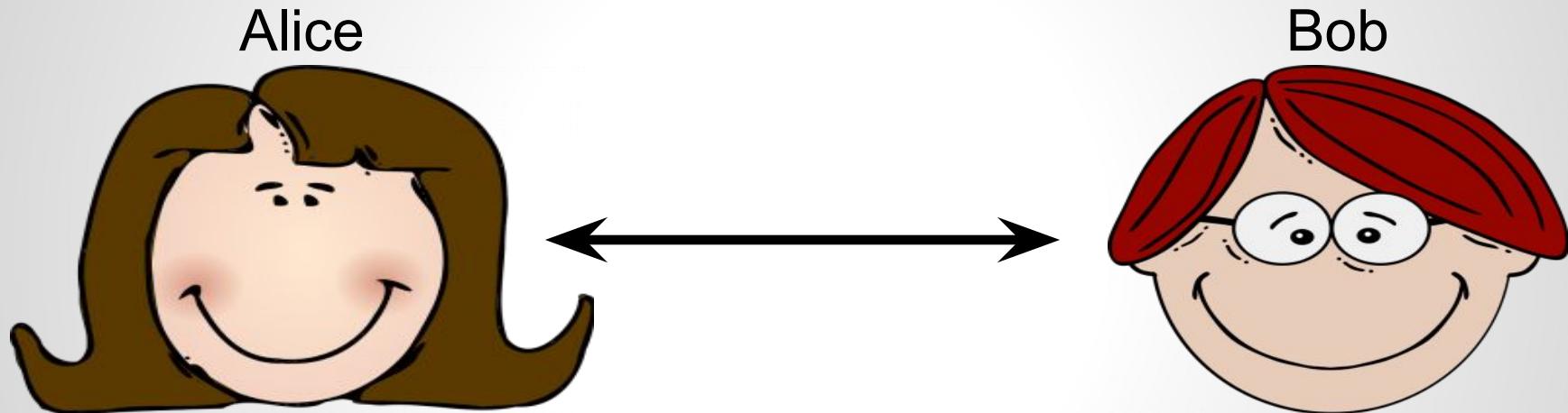


## 2 | Birth of the Telephone

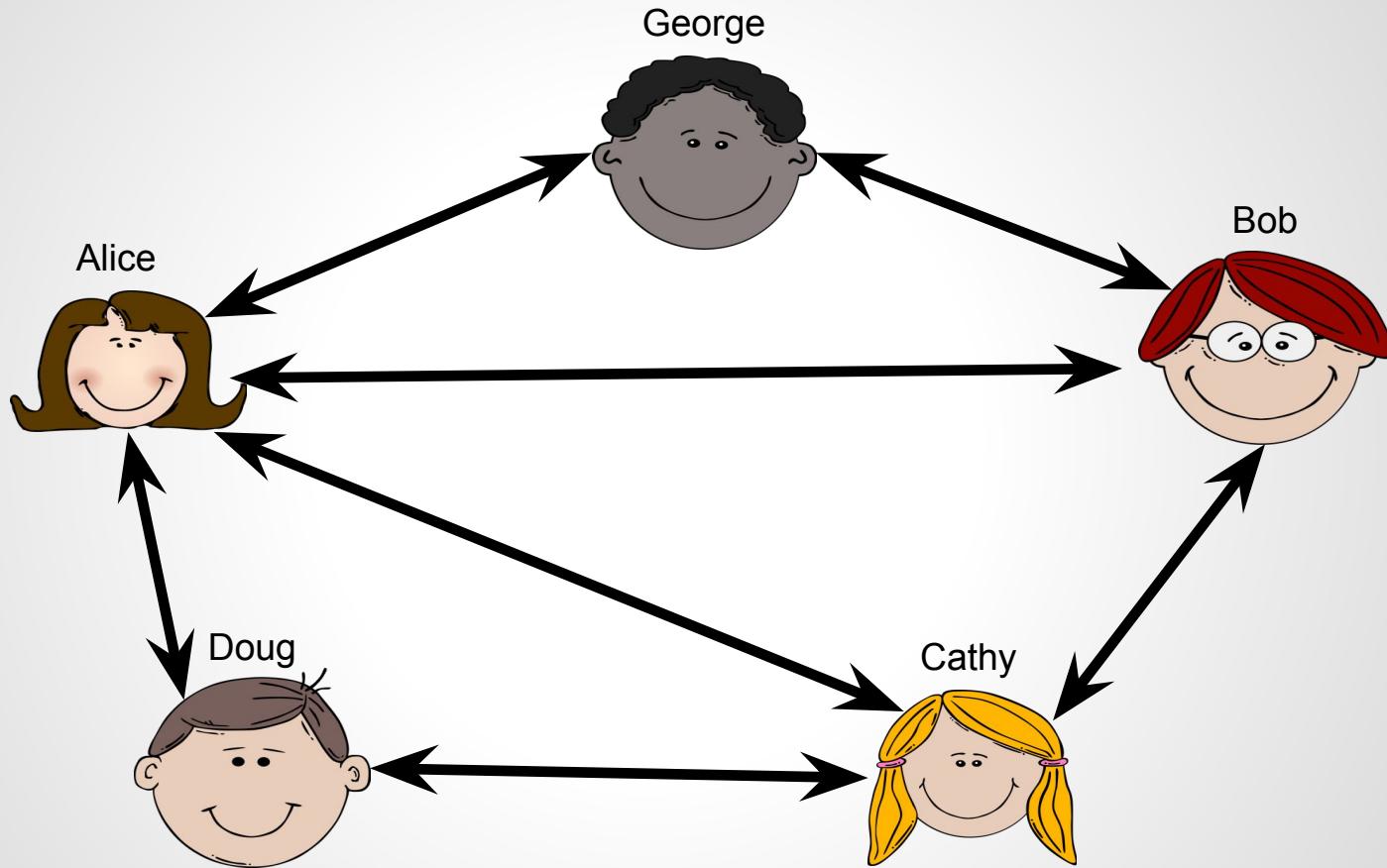
Intentionally Left Blank

# 3 – Control Plane

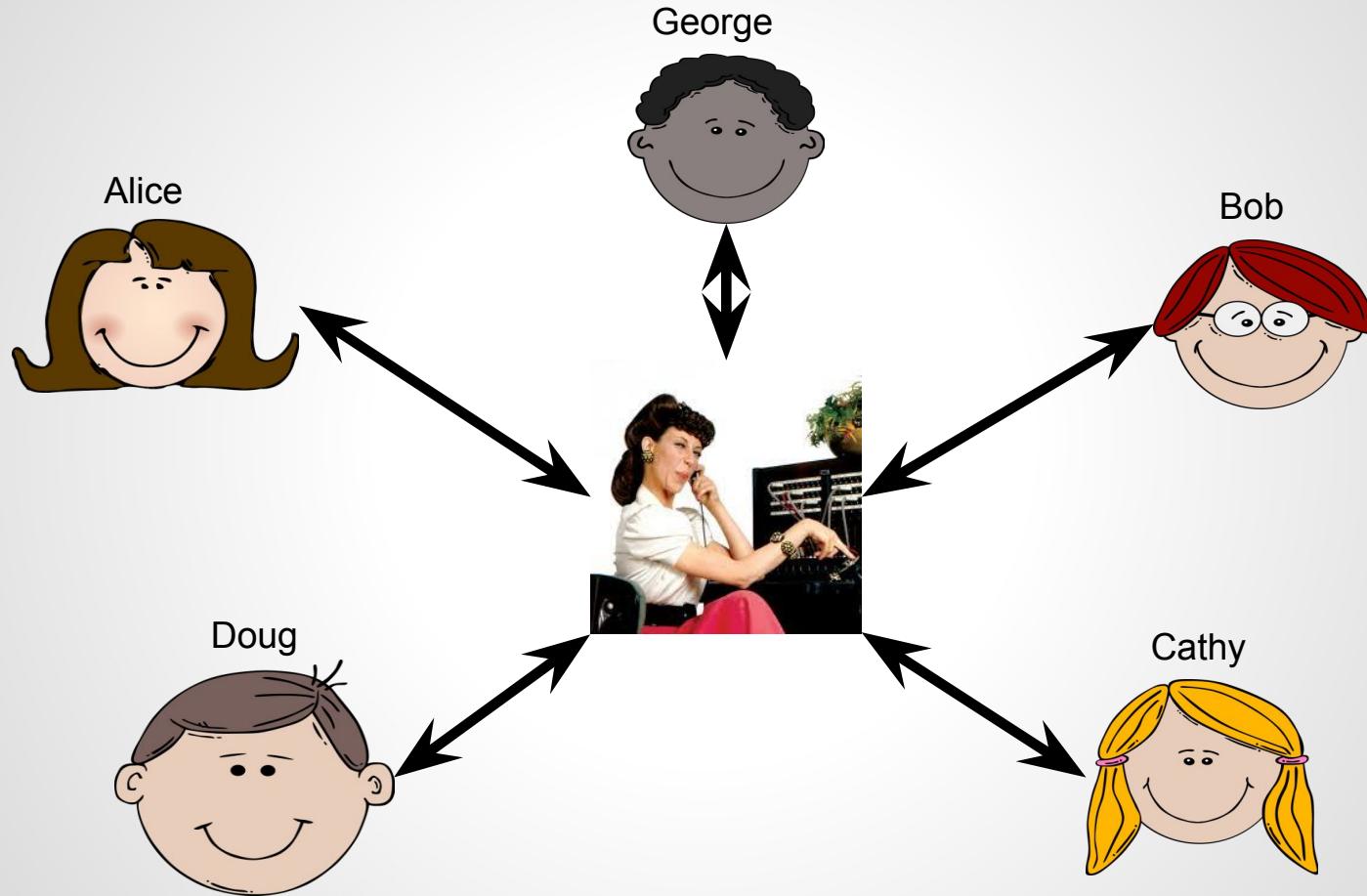
### 3 | Control Plane



### 3 | Control Plane



# 3 | Control Plane



### 3 | Control Plane

For  $N$  users, we need  $N$ -choose-2, written as  $\binom{N}{2}$  and this works out to  $N * (N - 1)/2$ .

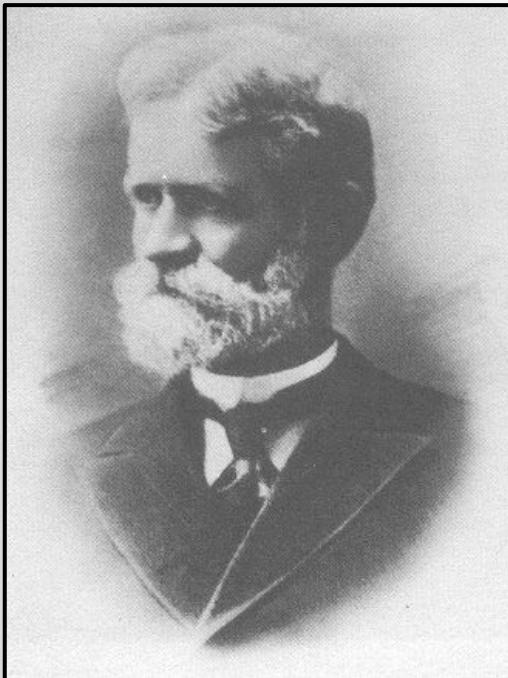
For large  $N$ , this is close to  $N^2$  and not at all practical. For a 1000 people neighborhood, you need 499,500 pairs!

**For the Star network that we just saw, this will be  $N + 1$  connections**

### 3 | Control Plane



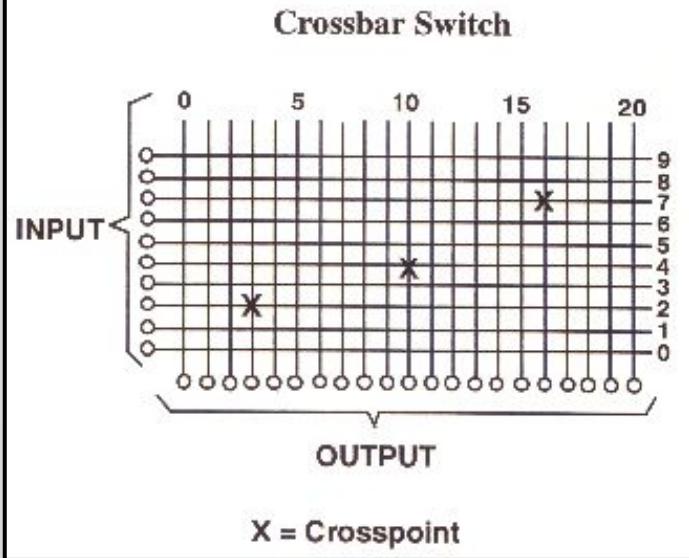
# 3 | Control Plane



Almon Brown Strowger



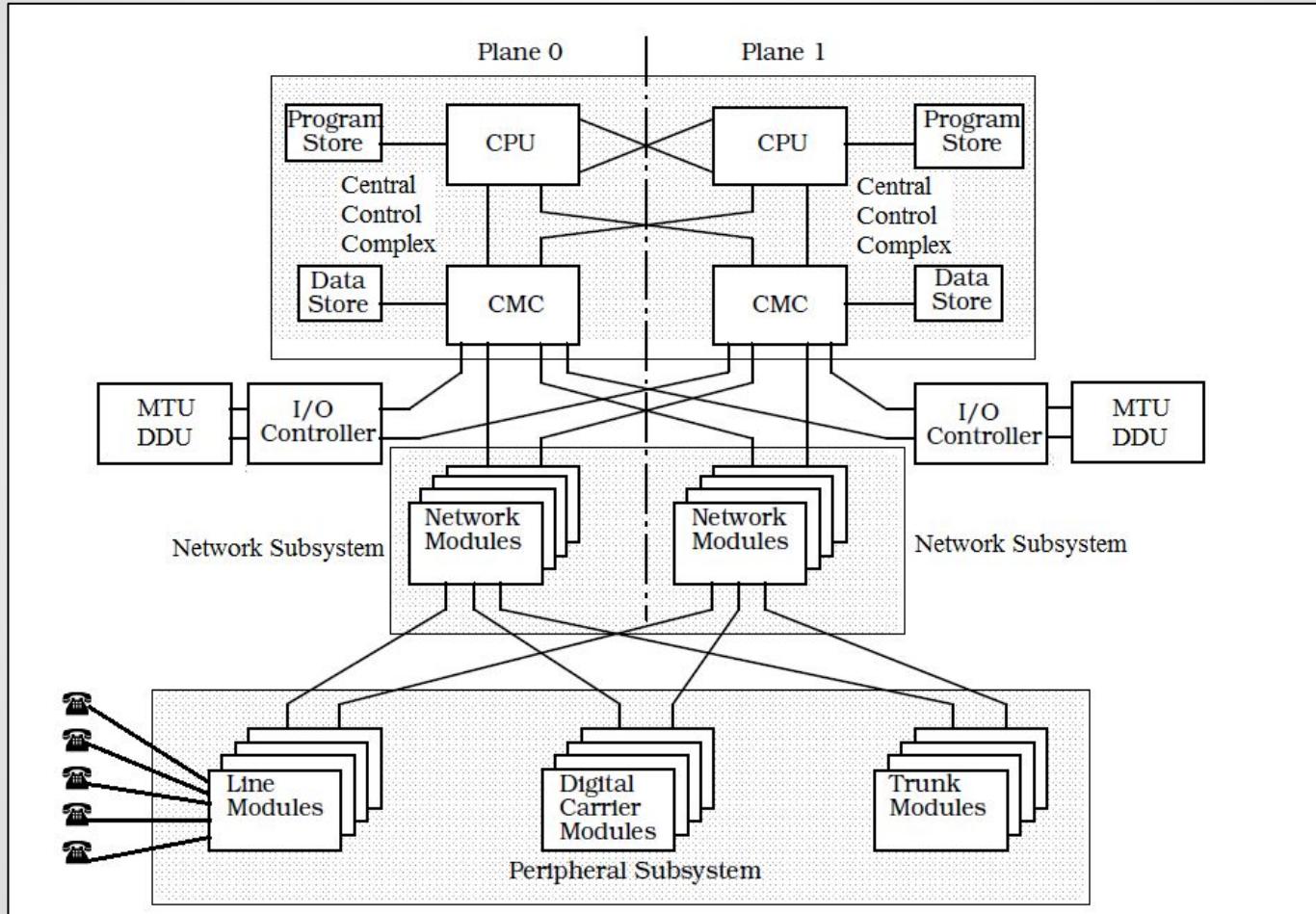
# 3 | Control Plane



# 3 | Control Plane



# 3 | Control Plane



### 3 | Control Plane



# 3 | Control Plane

Intentionally Left Blank

## 4 – Data Plane

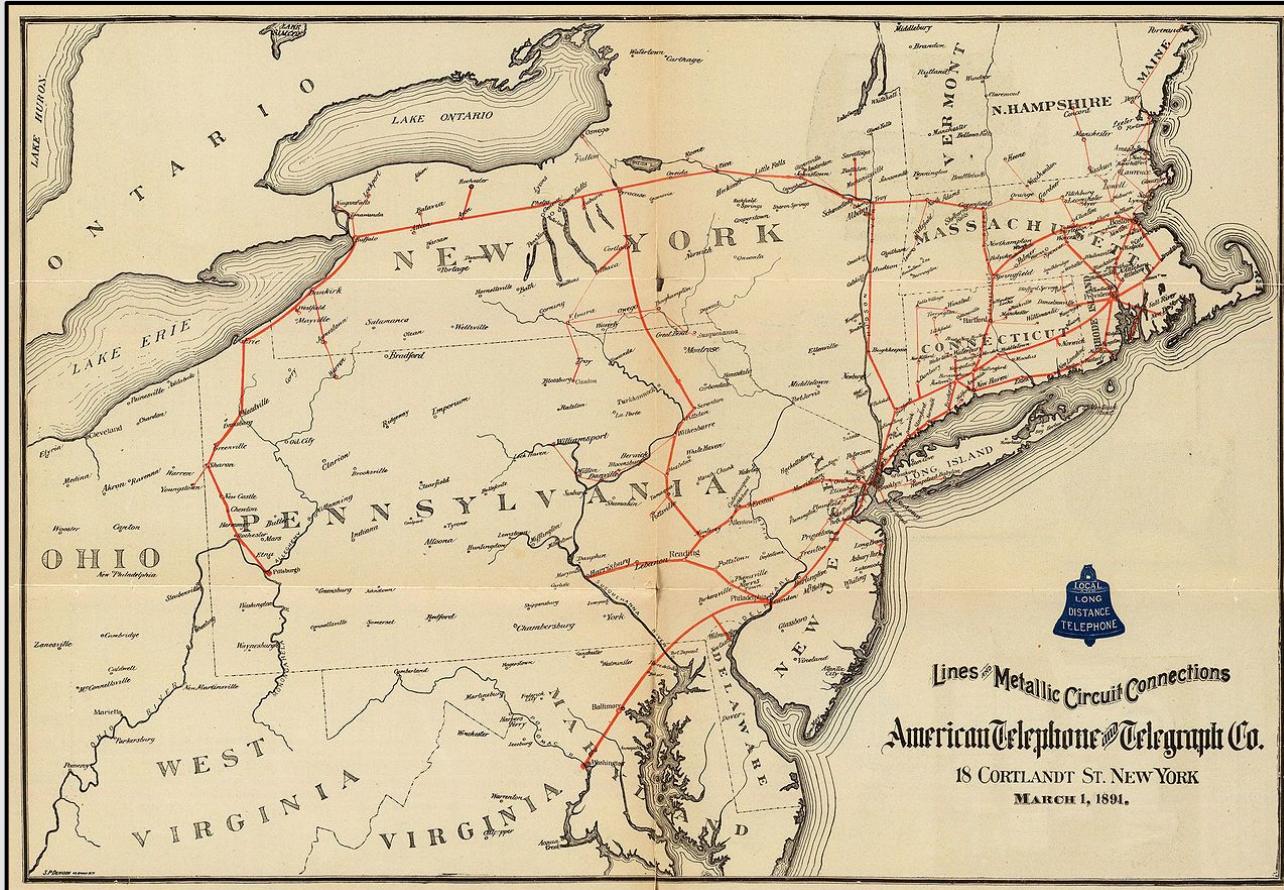
## Telephone Adoption



1890	49,000
1900	600,000
1905	2,200,000
1910	5,800,000

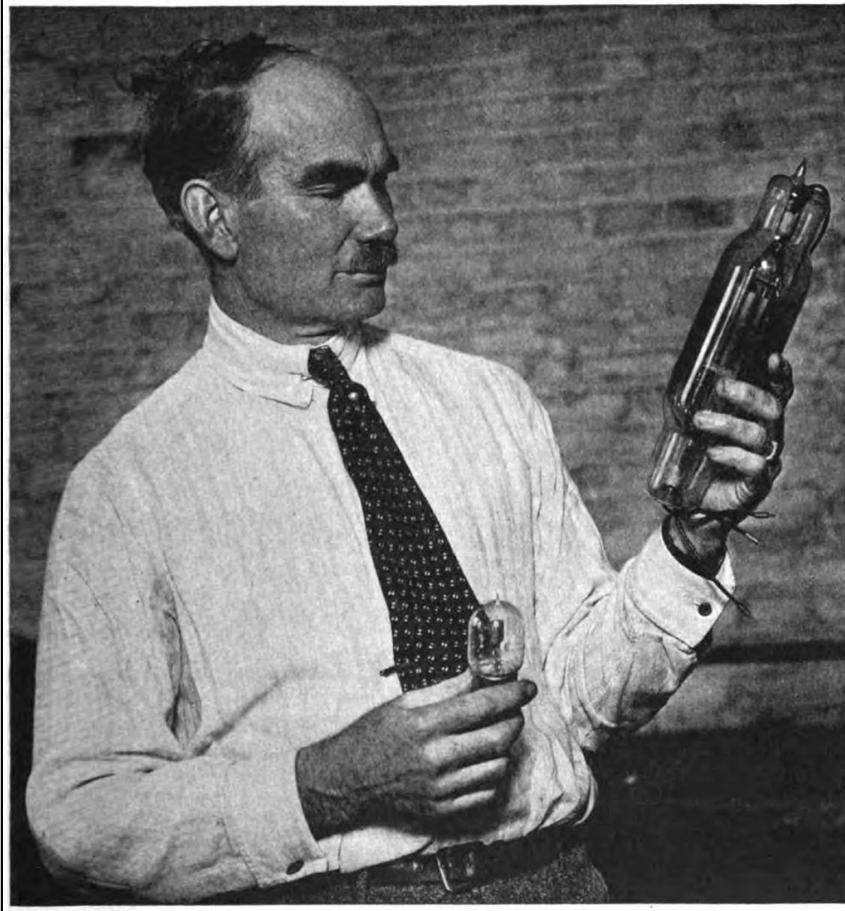


# 4 | Data Plane



March 1st, 1891

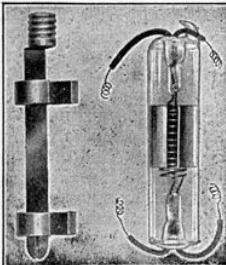
## 4 | Data Plane



**Lee de Forest**  
(August 26, 1873 –  
June 30, 1961)

## THE DE FOREST AUDION

"There is only one Audion—the De Forest"



THE GENUINE DE FOREST  
TUBULAR AUDION

Is sold separately to any amateur who prefers to build his own Audion **Price \$5.50**

Adapter 40 cents extra.  
*Get the Bulletin (X16)*

**WARNING**—You are entitled to the genuine Audion, guaranteed by the owners of the Audion patents, when making an investment of this kind. Any evacuated detector having a filament, a grid and a plate, as well as other types, are covered by our patents, and several irresponsible infringers are being prosecuted. To be safe and get full value for your money, insist on the genuine De Forest Audion.

SEND FOR BULLETINS X16 AND M16 DESCRIBING AUDION  
**Detectors, Audion Amplifiers and Audion Receiving Cabinets**

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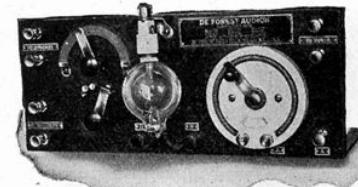
DE FOREST RADIO TELEPHONE & TELEGRAPH CO.

101 PARK AVENUE

-:-

NEW YORK, N. Y.

*Makers of the Highest Grade Receiving Equipment in the World*



THE TYPE RJ9 DE FOREST AUDION  
DETECTOR

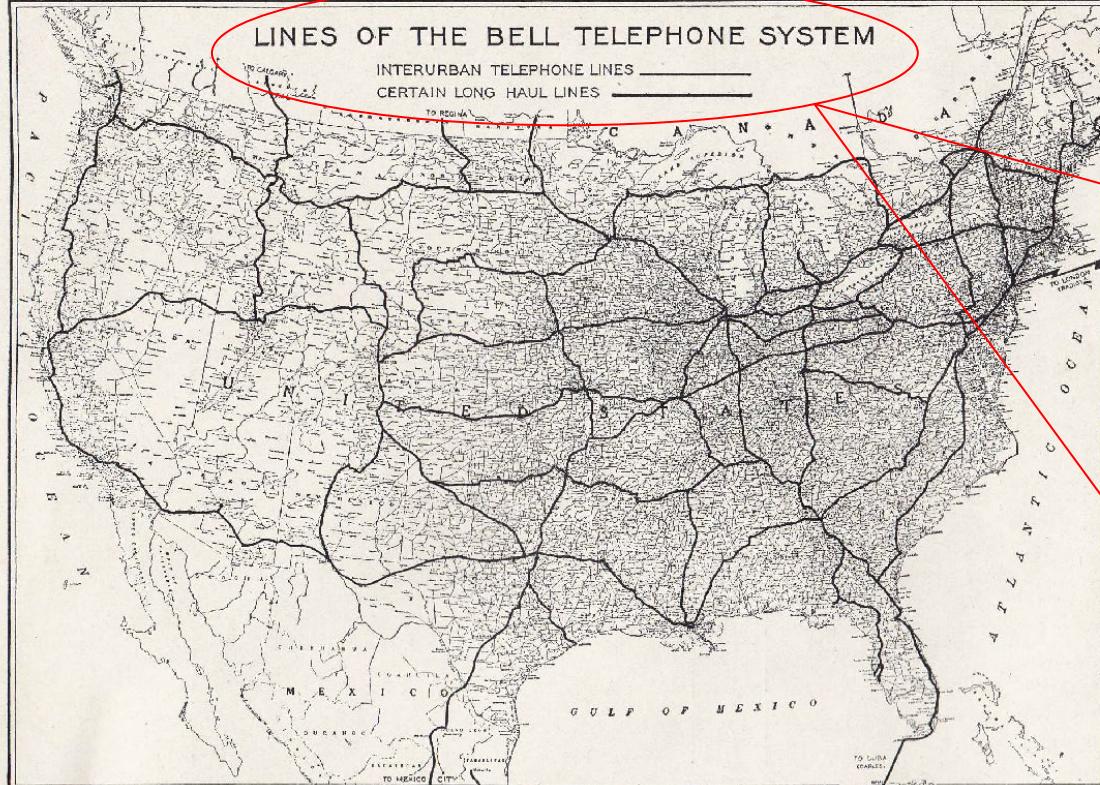
Incorporates the Audion Bulb and the genuine De Forest patented circuits with the most approved accessories needed to form a complete detector.

The most popular Audion Detector ever offered. **Price \$14.00**

*Get the Bulletin (M16)*



# 4 | Data Plane



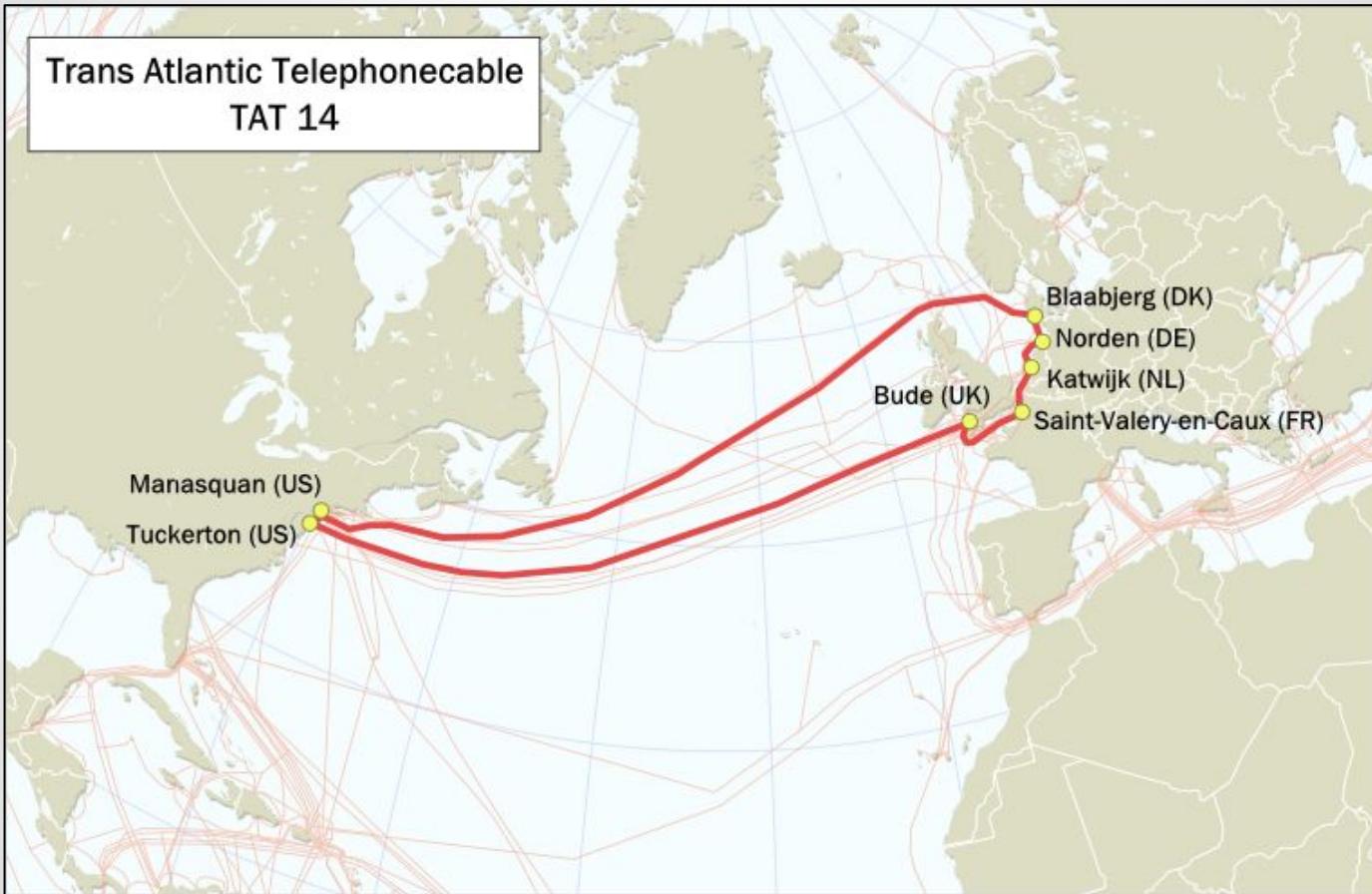
Interurban Telephone  
Lines \_\_\_\_\_

Certain Long Haul  
Lines \_\_\_\_\_

THE GROWTH OF THE TRANSCONTINENTAL LINES OF THE BELL TELEPHONE SYSTEM

The first transcontinental line to San Francisco was finished in 1915, the second to Los Angeles in 1923, and the third to Seattle and Portland was opened January 10, 1927.

# 4 | Data Plane



# **Lesson 2**

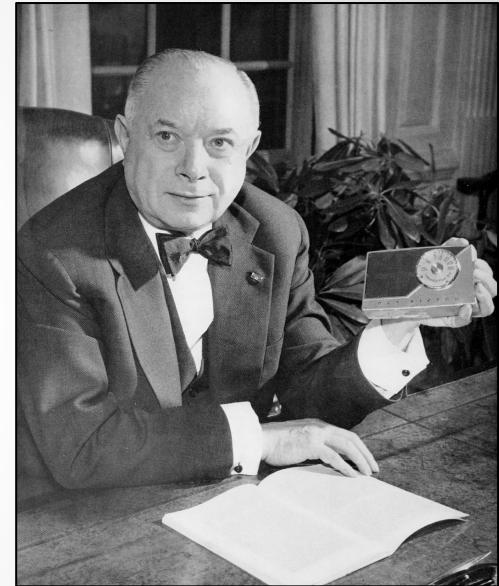
Broadcast Network

# Lesson 2 | Broadcast Network

1 - Broadcast Innovations



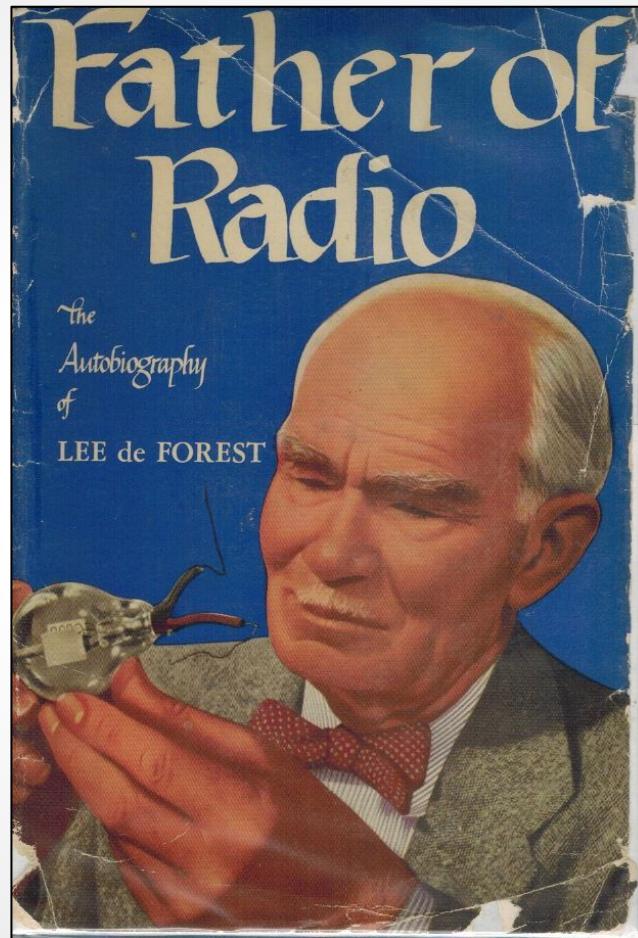
2 - Broadcast Industry



3 - Content is King

# 1 – Broadcast Innovations

# 1 | Broadcast Innovations



# 1 | Broadcast Innovations



E. H. ARMSTRONG

The discoverer of the "feed-back" circuit, in the uniform of a major in the Signal Corps during the war

DECEMBER 12, 1914

ELECTRICAL WORLD

1149

## Operating Features of the Audion

Explanation of its action as an amplifier,  
as a detector of high-frequency oscillations  
and as a "valve." By E. H. Armstrong

ALTHOUGH the audion has been in use for several years as an amplifier and a detector of high-frequency oscillations, the explanations advanced to account for its action do not appear to be satisfactory. With the idea of pointing out some features of operation which heretofore do not seem to have been

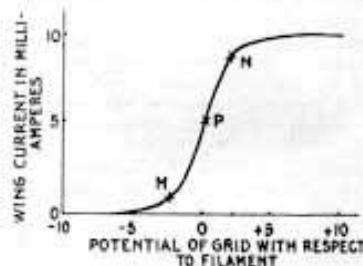


FIG. 1—VARIATION OF WING CURRENT WITH GRID POTENTIAL

with respect to the filament, but only one grid was employed. It was found that, under similar conditions of filament temperature and voltage of the battery  $B_g$ , a considerably smaller current was obtained between the filament and plate on the side in which the grid was inserted. In both measurements the grid was left entirely free of any connection with the rest of the apparatus. Obviously the grid obstructed the flow of the thermionic current. Investigation showed that this was due to the charge accumulating on the grid when exposed to bombardment by the electrons passing from

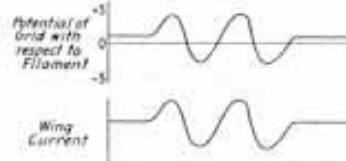
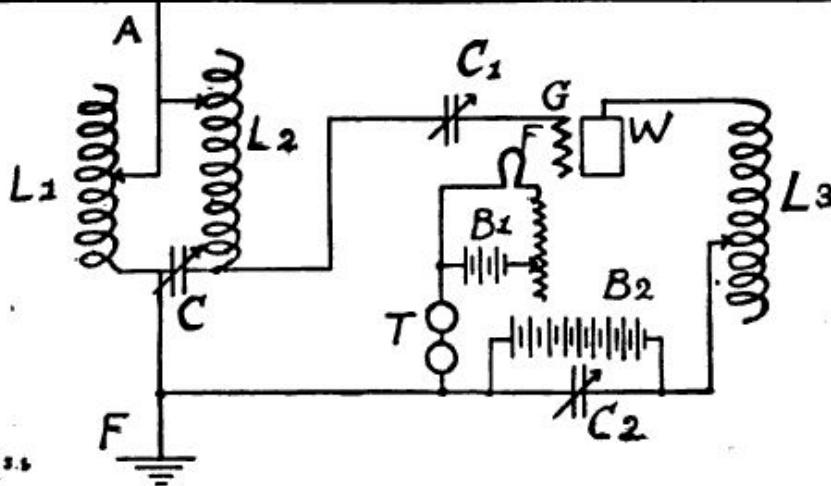


FIG. 4—TIME VARIATION OF GRID POTENTIAL AND WING CURRENT

# 1 | Broadcast Innovations

THE ORIGINAL DRAWING OF THE FEED-BACK CIRCUIT WHICH  
LARGELY DETERMINED THE COURT IN ARMSTRONG'S FAVOR



In the County of  
New York, U.S.A.

On the Thirtieth day of January 1913  
appeared before me  
E. H. Armstrong who  
signed this diagram  
before me.

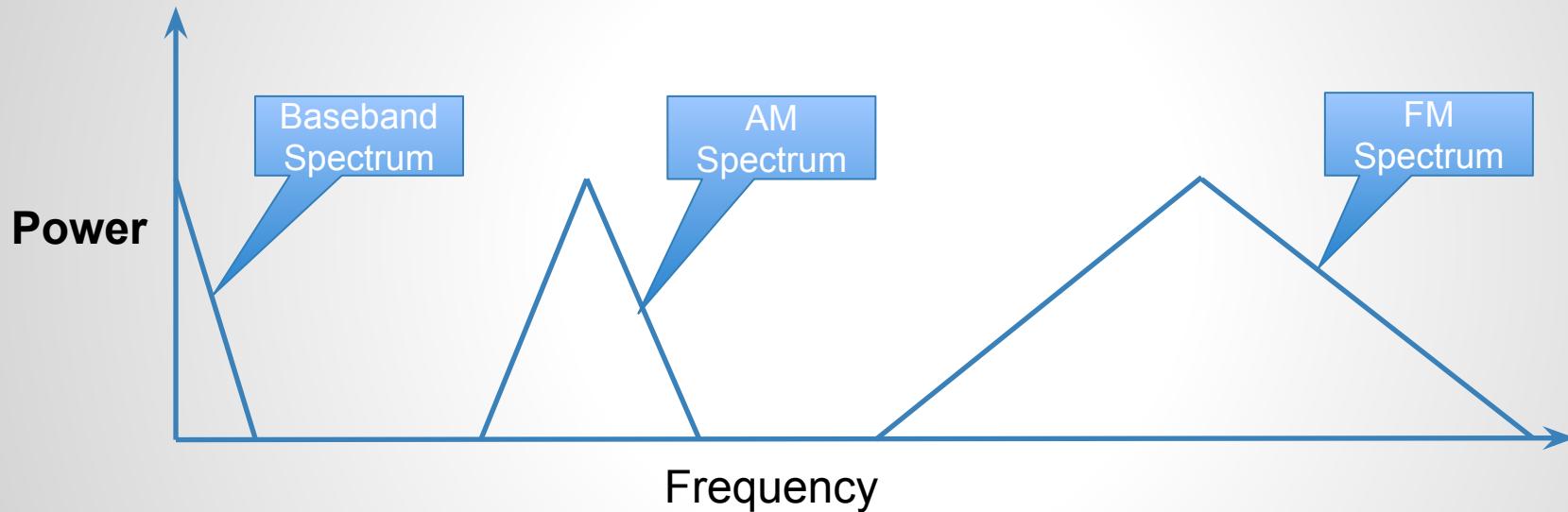
E. H. Armstrong  
Notary Public  
New York County

E. H. Armstrong  
Greystone  
N.Y.

# 1 | Broadcast Innovations



# 1 | Broadcast Innovations

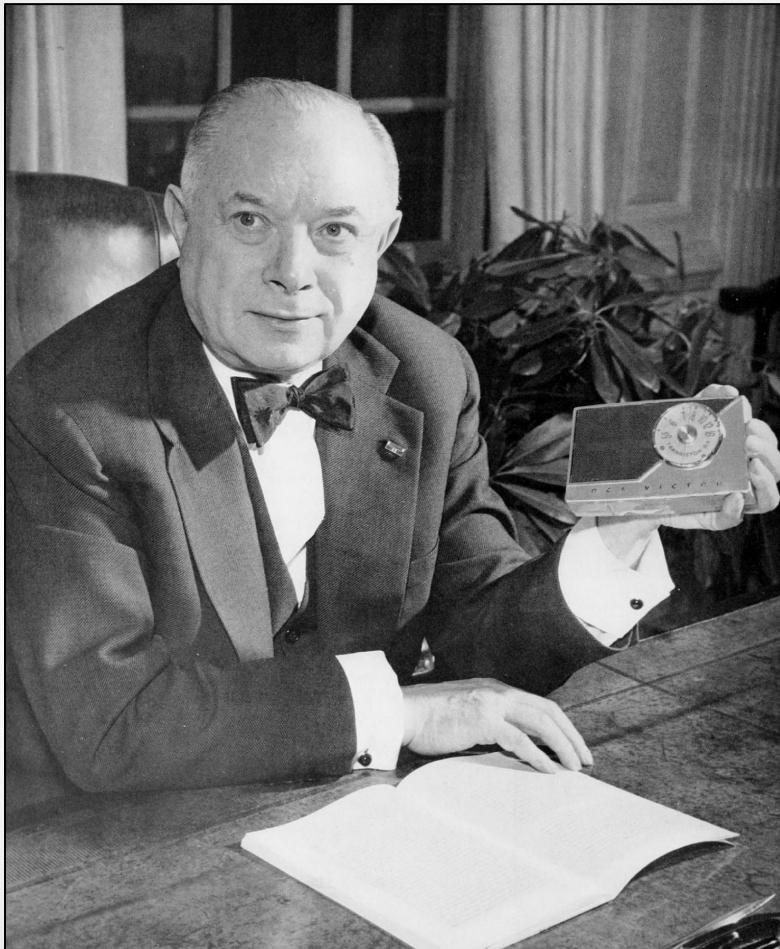


# 1 | Broadcast Innovations



## 2 – Broadcast Industry

## 2 | Broadcast Industry



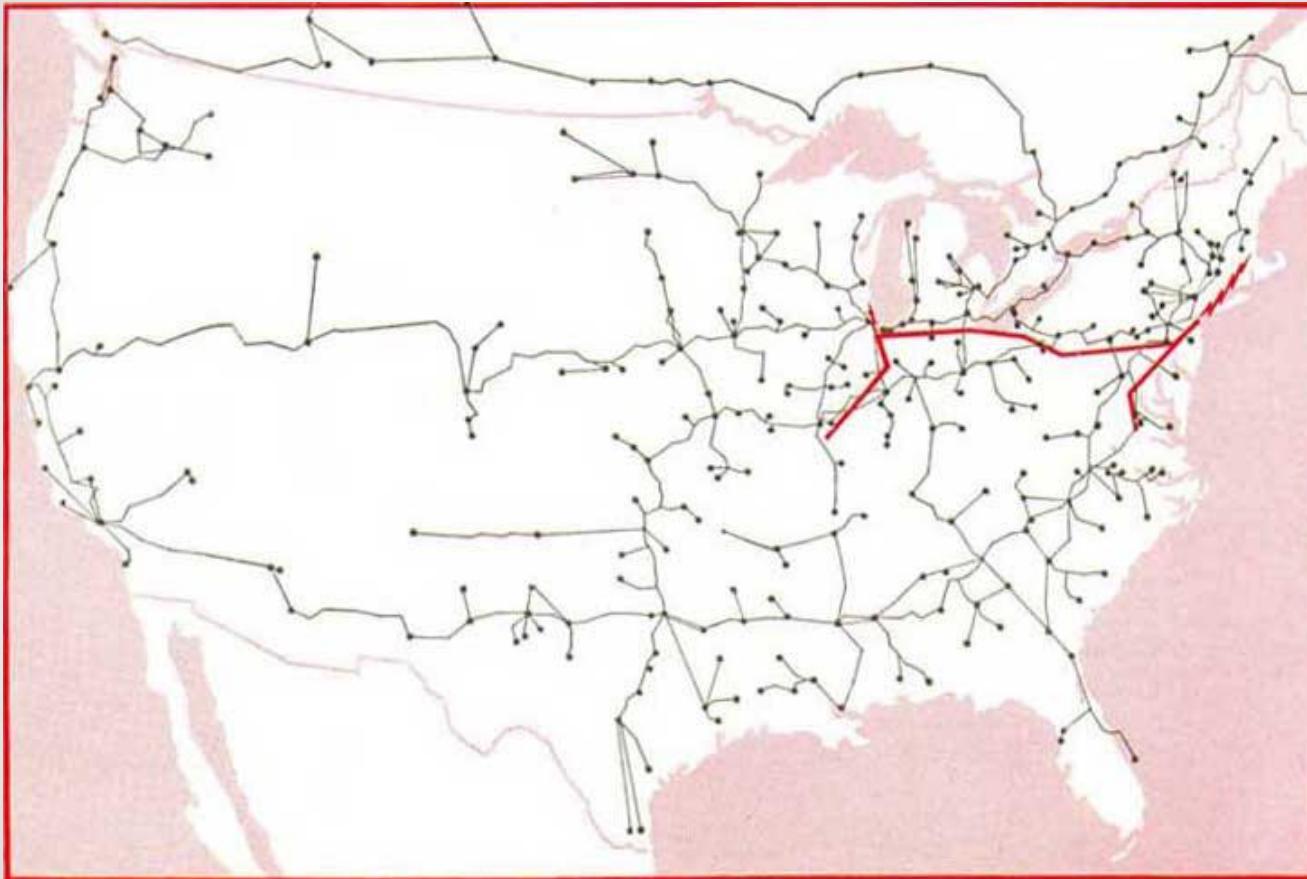
## 2 | Broadcast Industry



## 2 | Broadcast Industry



## 2 | Broadcast Industry



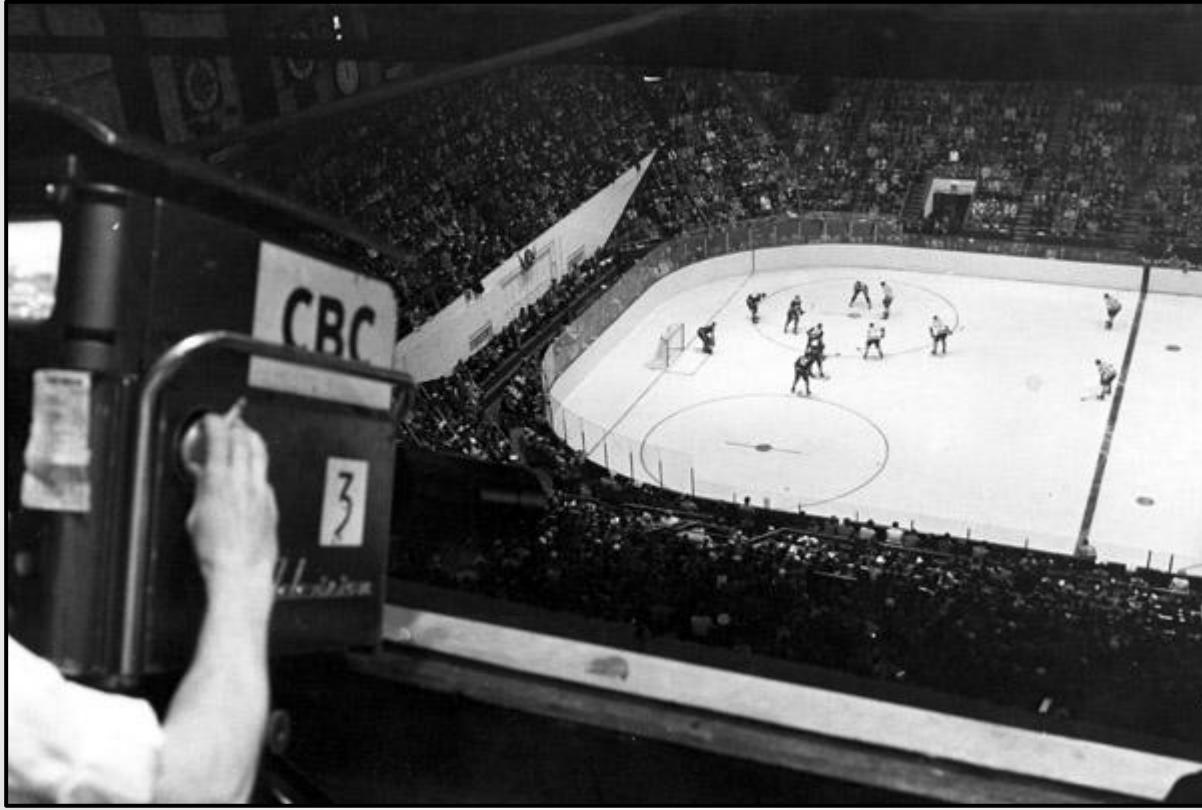
TV network from 1950 in **RED** and today's network in black

## 3 – Content is King

# 3 | Content is King



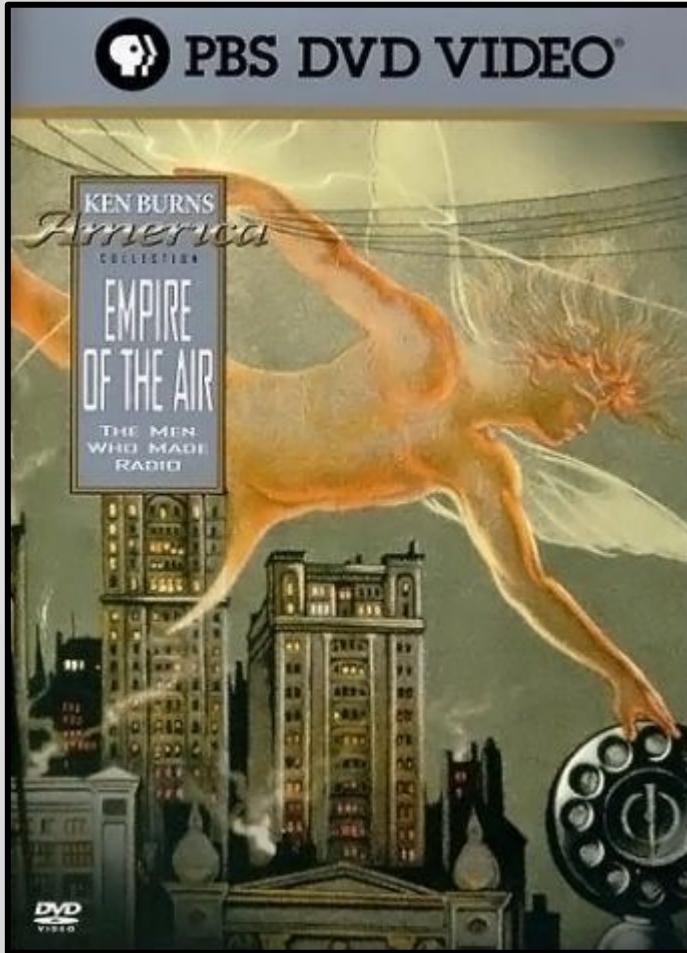
# 3 | Content is King



## 2 | Broadcast Industry



## 2 | Broadcast Industry



Ken Burns Documentary  
Empire of the Air  
The men who made radio

# Lesson 3

AT&T Innovations

# Lesson 3 | AT&T Innovations

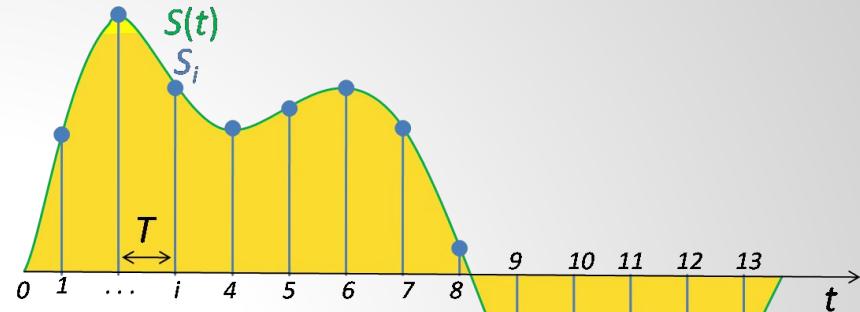
1 - Sampling: Analog  $\longleftrightarrow$  Digital

2 - Audio and Speech Coding

3 - Shannon: Information Theory

4 - Transistor

5 - C and Unix



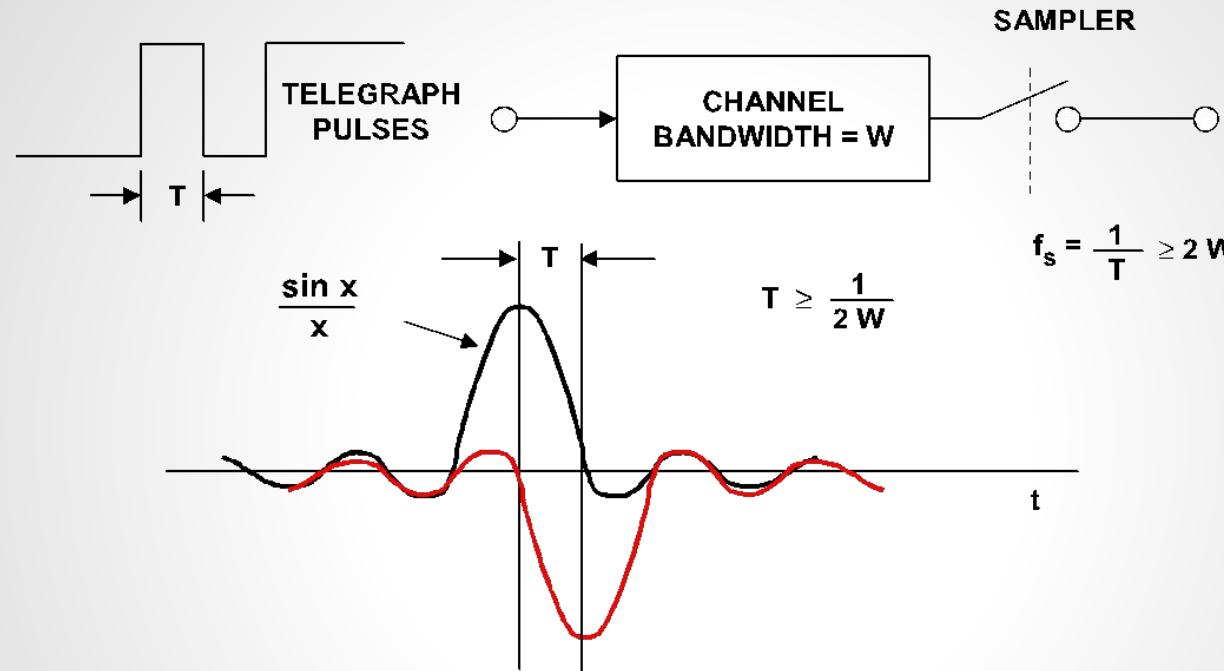
# 1 – Sampling: Analog $\longleftrightarrow$ Digital

# 1 | Sampling: Analog $\longleftrightarrow$ Digital



Harry Nyquist

# 1 | Sampling: Analog ↔ Digital



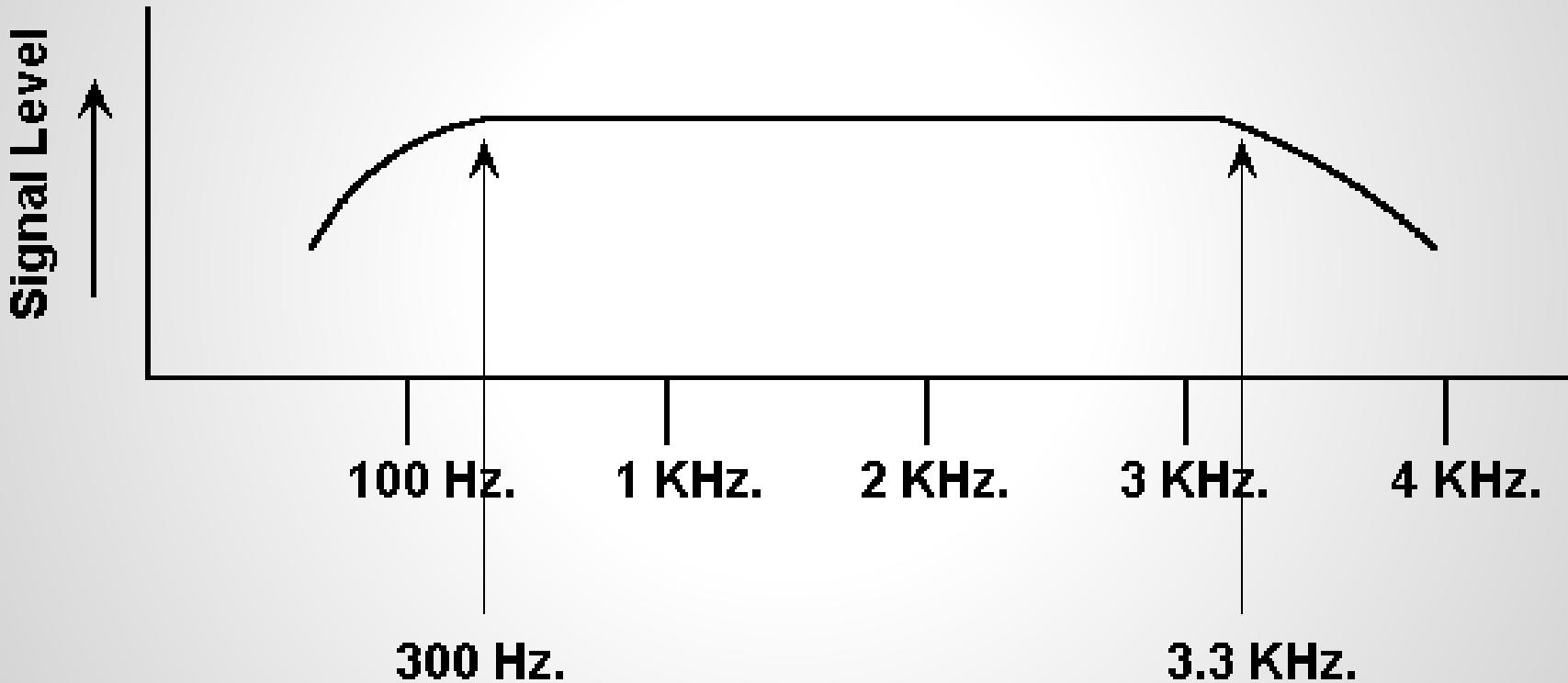
- ◆ Up to  $2W$  pulses per second can be transmitted over a channel which has a bandwidth  $W$ .
- ◆ If a signal is sampled instantaneously at regular intervals at a rate at least twice the highest significant signal frequency, then the samples contain all the information in the original signal.

# 1 | Sampling: Analog ↔ Digital

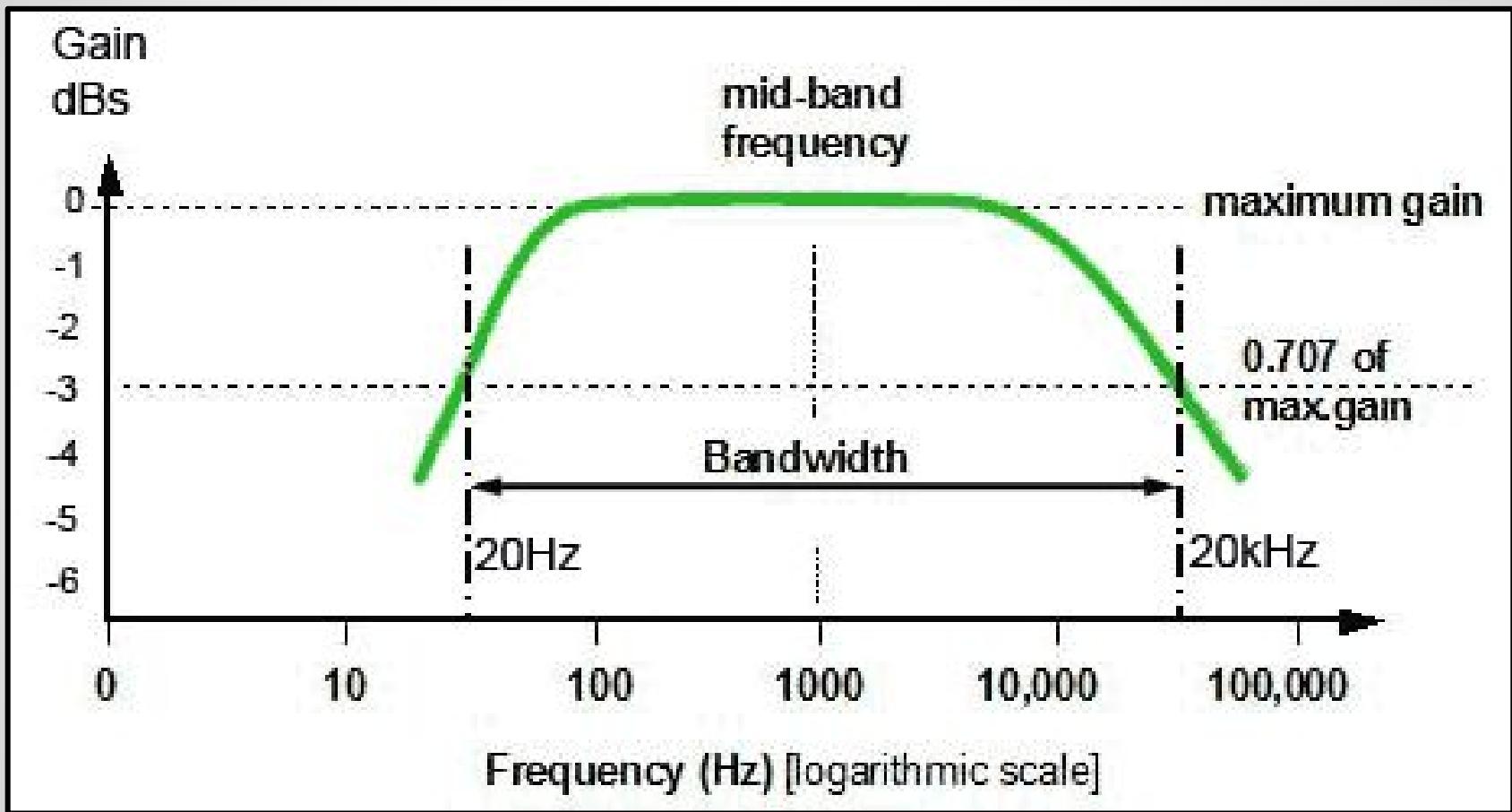


# 1 | Sampling: Analog $\longleftrightarrow$ Digital

**Normal POTS Frequency Response Curve**



# 1 | Sampling: Analog $\longleftrightarrow$ Digital



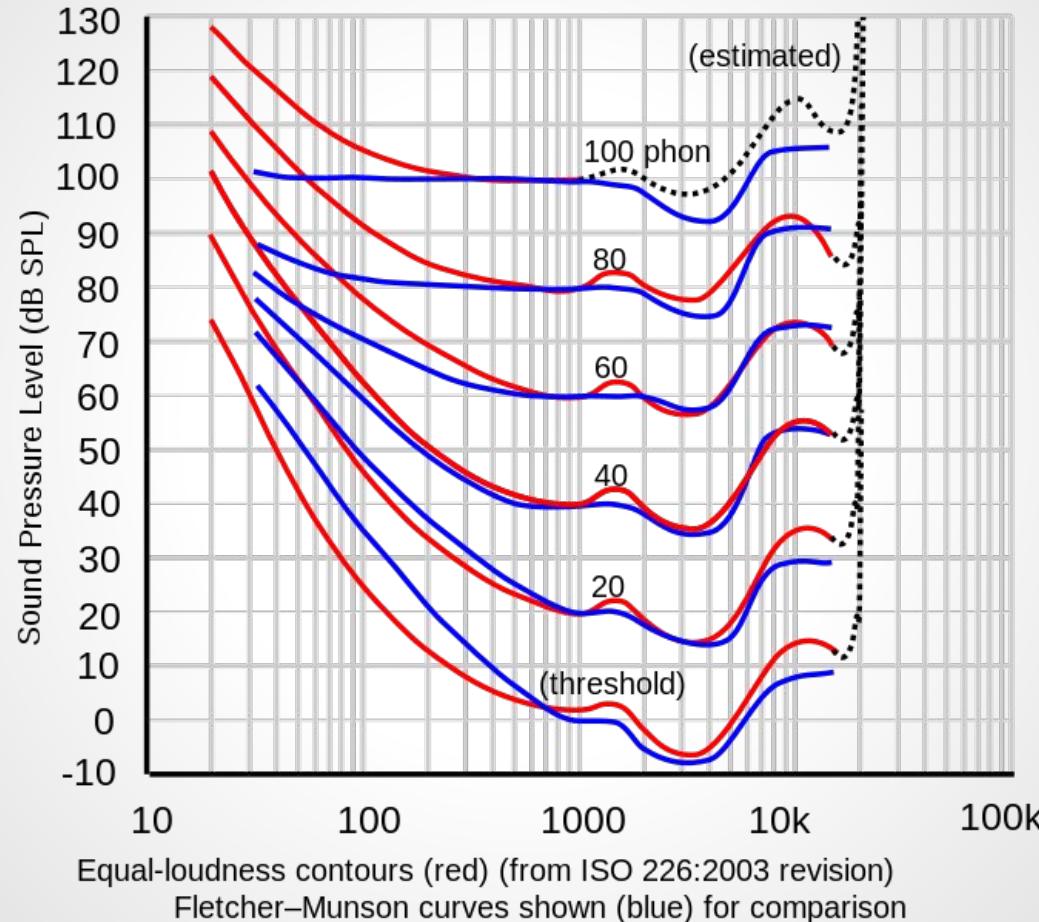
## 2 – Audio and Speech Coding

## 2 | Audio Coding

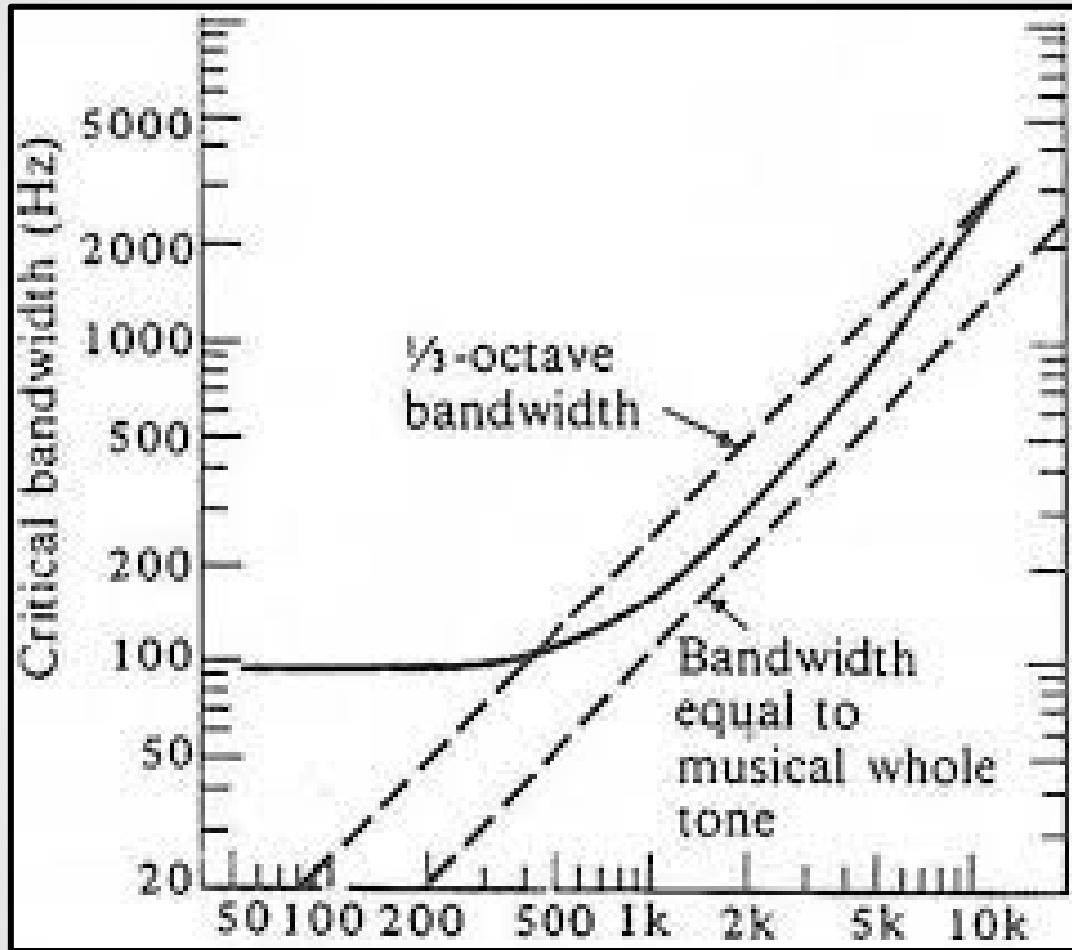


**Harvey Fletcher**  
(September 11, 1884 – July 23,  
1981)

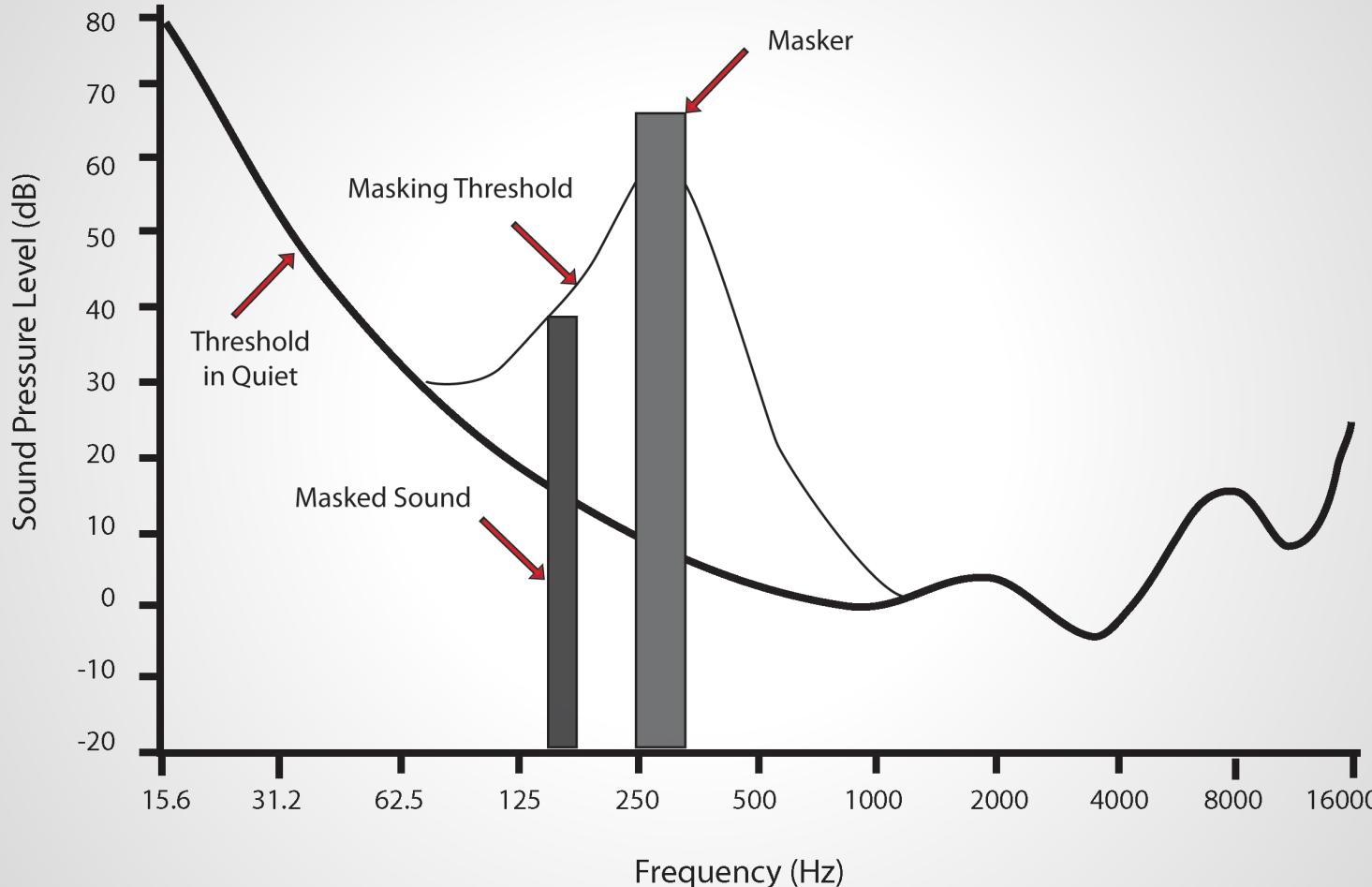
## 2 | Audio Coding



## 2 | Audio Coding

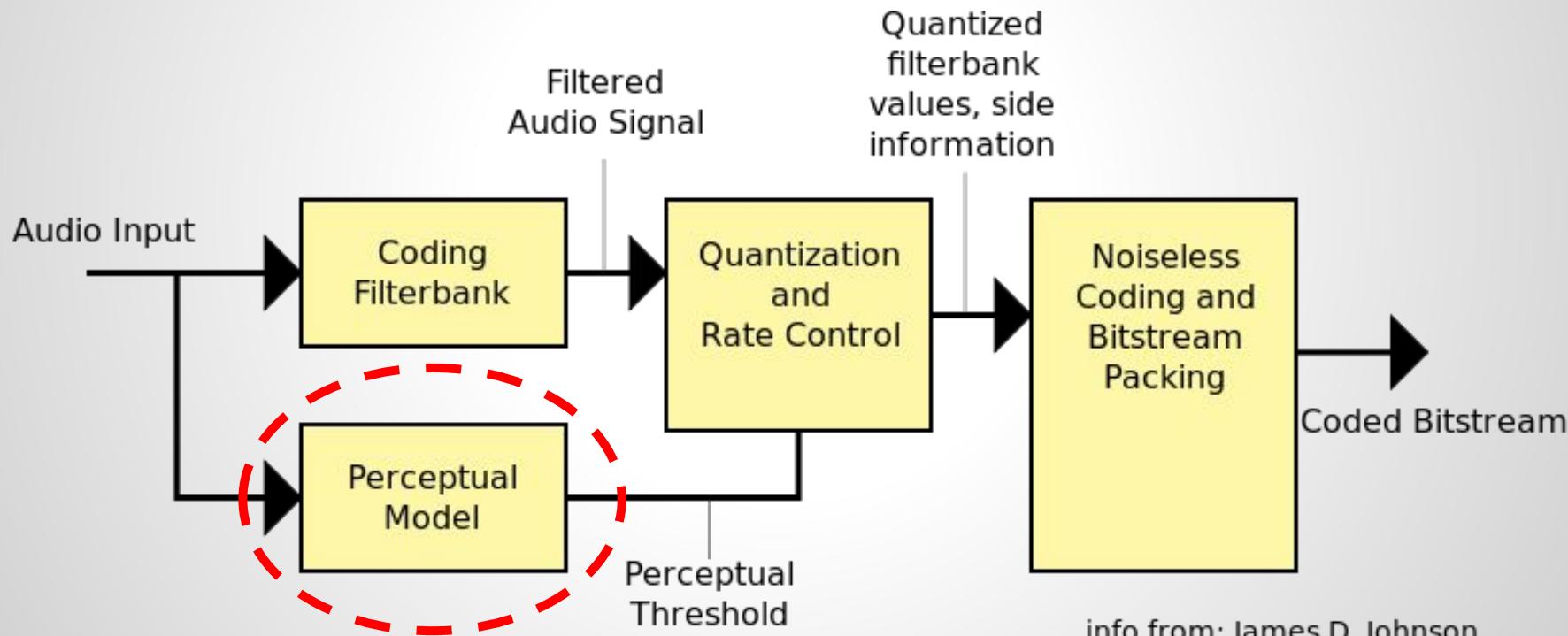


## 2 | Audio Coding



Block Diagram of:

# Perceptual Audio Coder



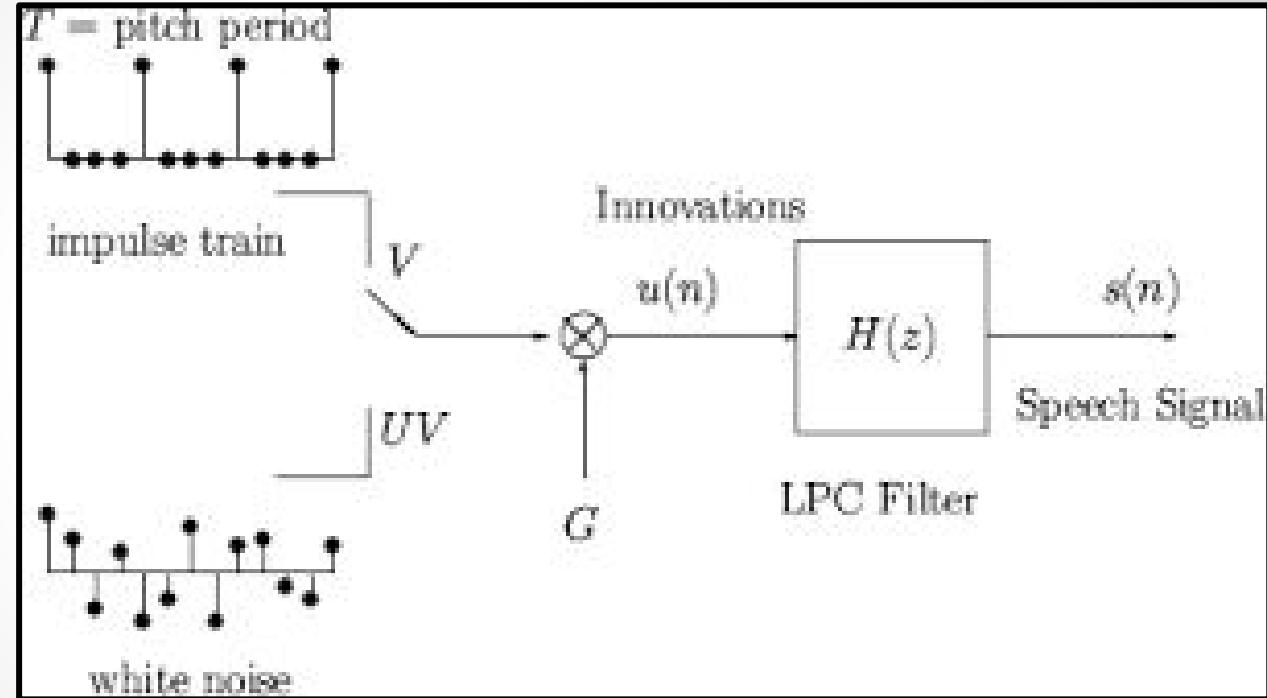
info from: James D. Johnson

## 2 | Audio Coding



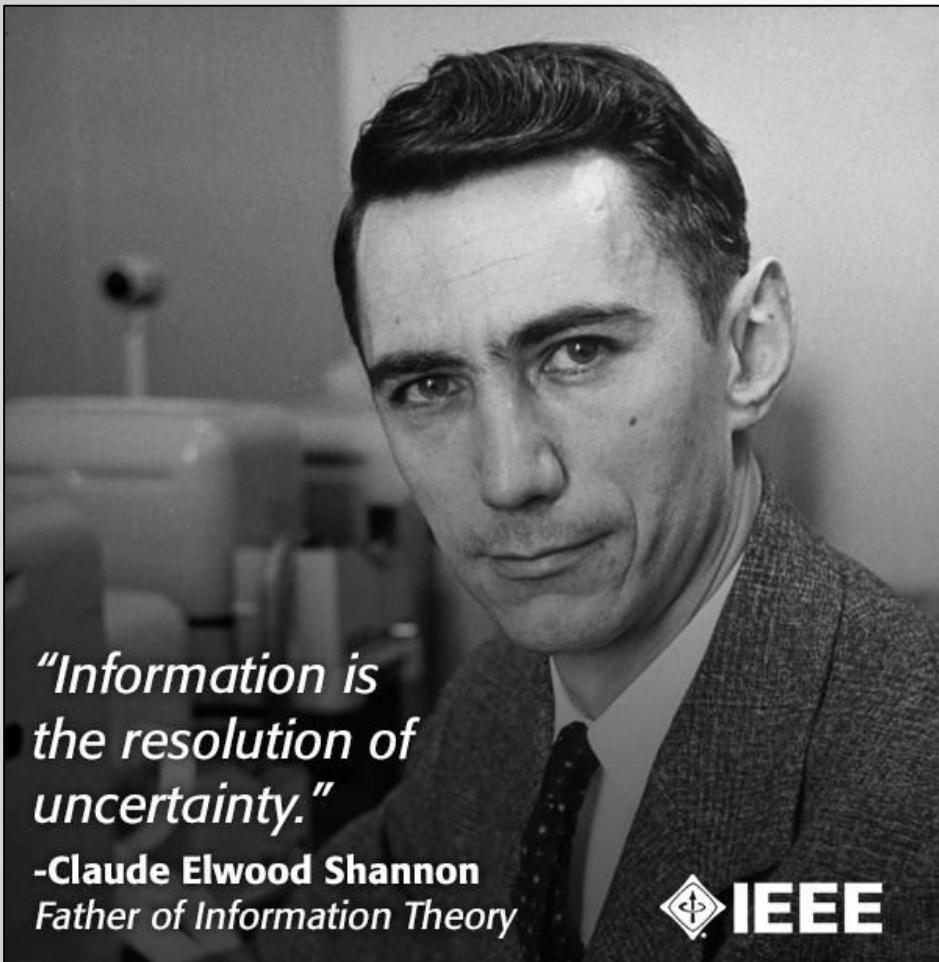
**Bishnu Atal**  
AT&T

### Linear Predictive Coding (LPC)



# 3 – Shannon : Information Theory

# 3 | Shannon: Information Theory

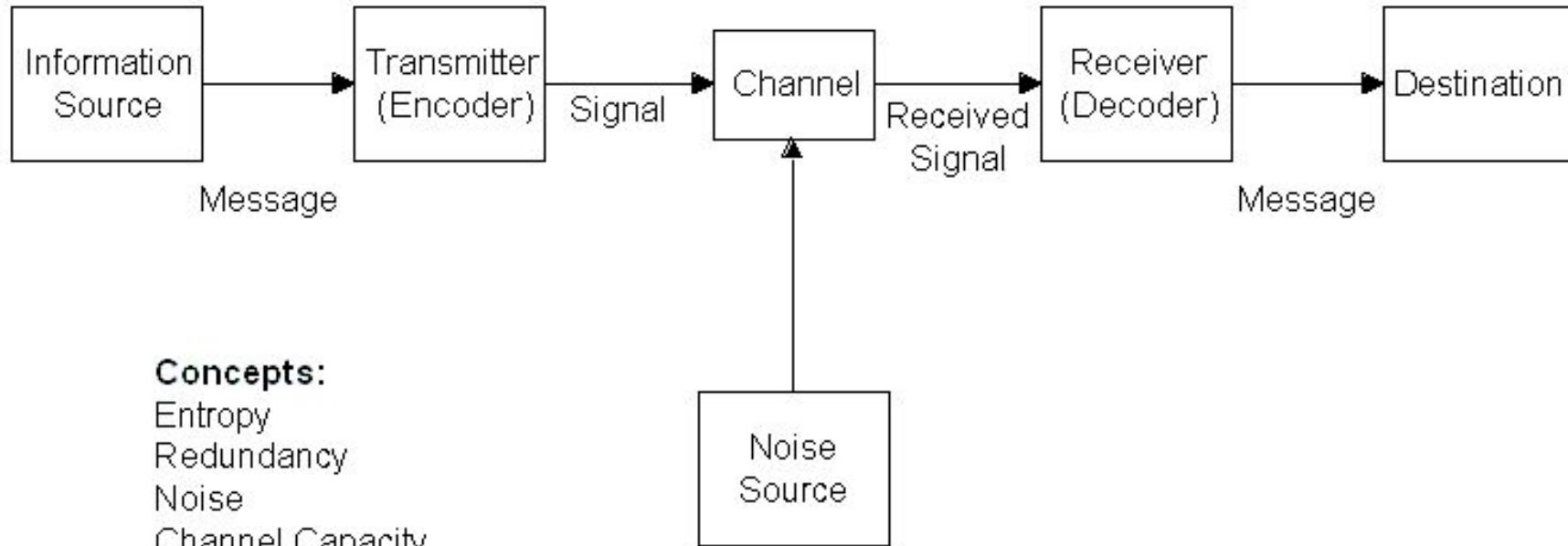


IEEE



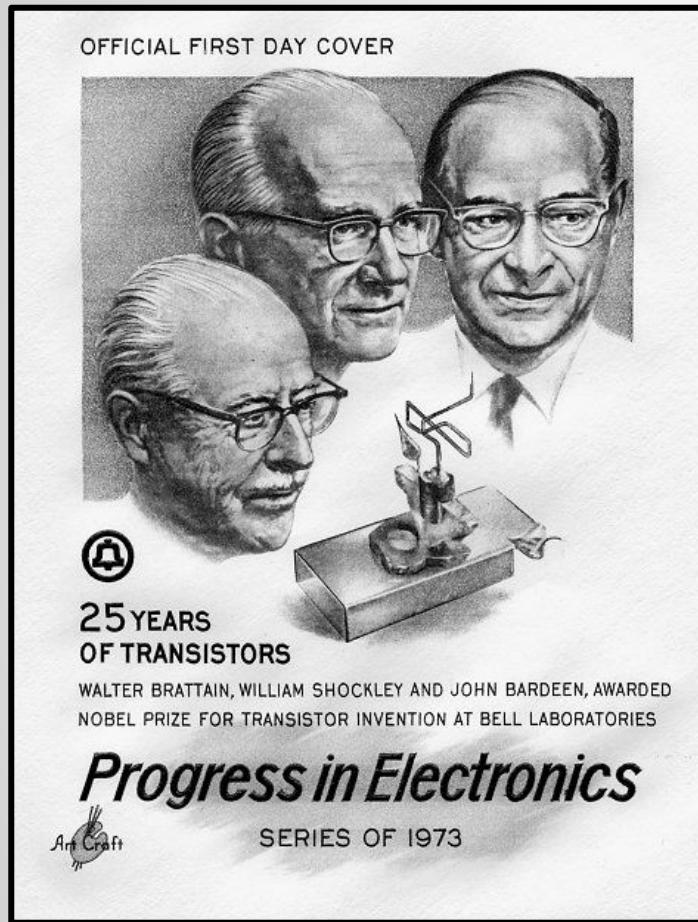
### 3 | Shannon: Information Theory

## The Shannon-Weaver Mathematical Model, 1949



# 4 – Transistor

# 4 | Transistor



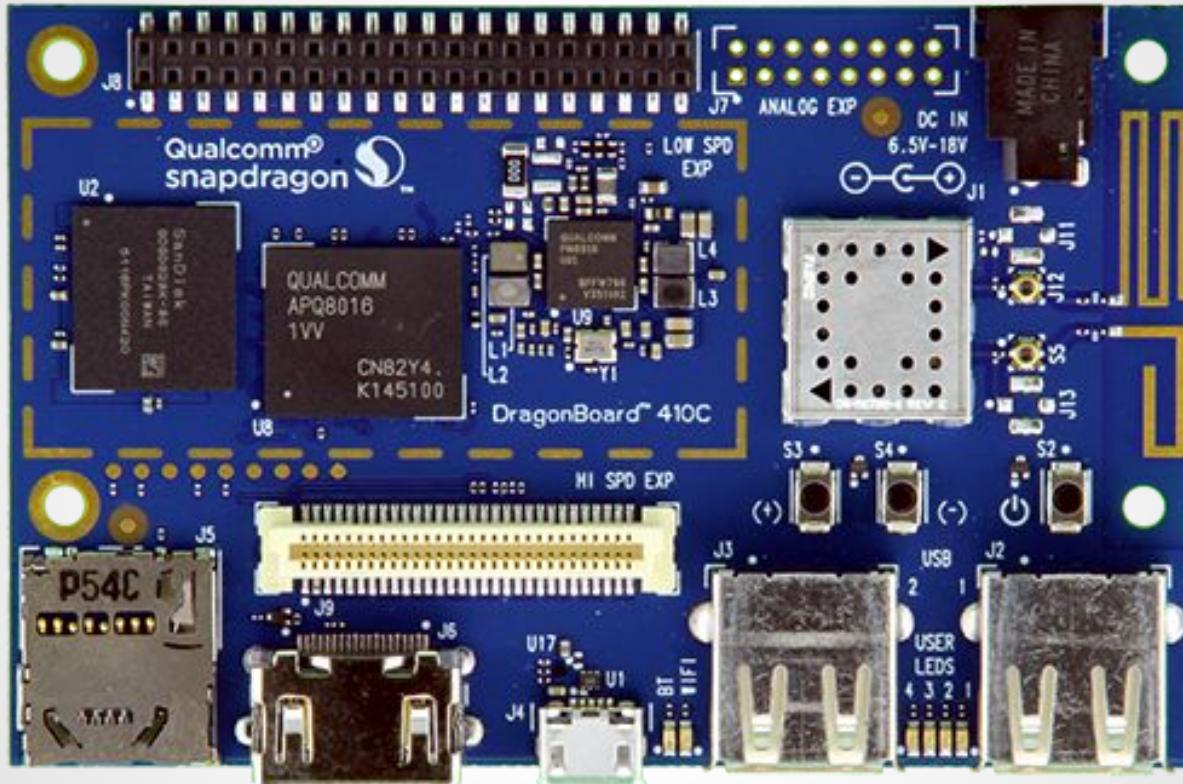
# 4 | Transistor



# 4 | Transistor

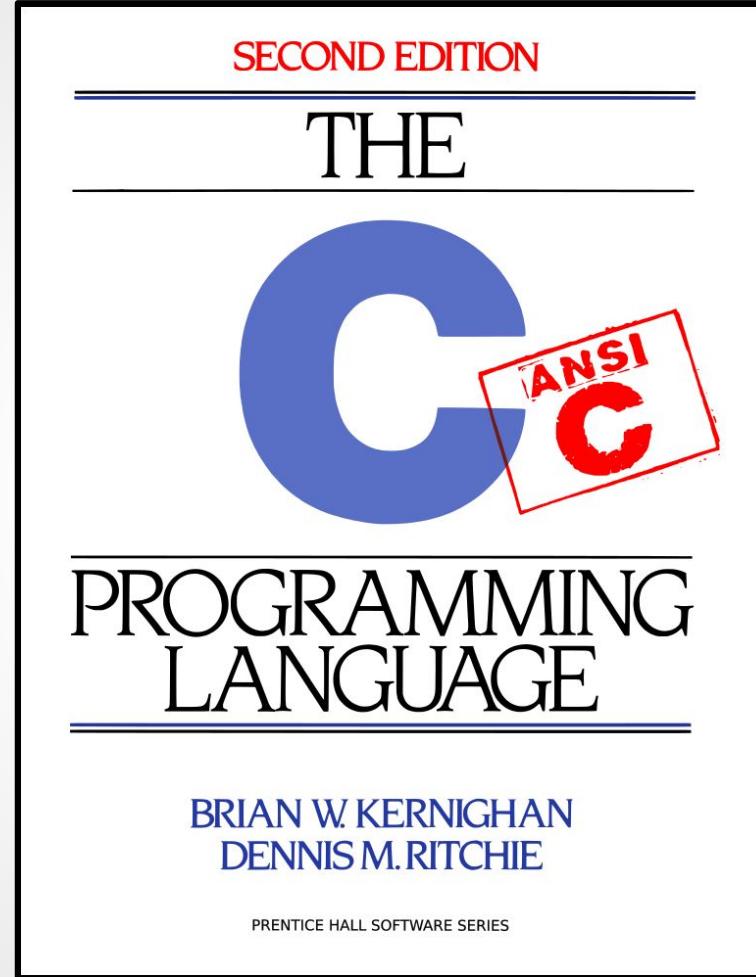


# 4 | Transistor



**DragonBoard™ 410c**

# 5 – C and Unix





Ken Thompson and Dennis Ritchie at the White House

# 5 | C and Unix



# Lesson 4

Rise and Fall of AT&T

# Lesson 4 | Rise and fall of AT&T

1 - Regulated Monopoly

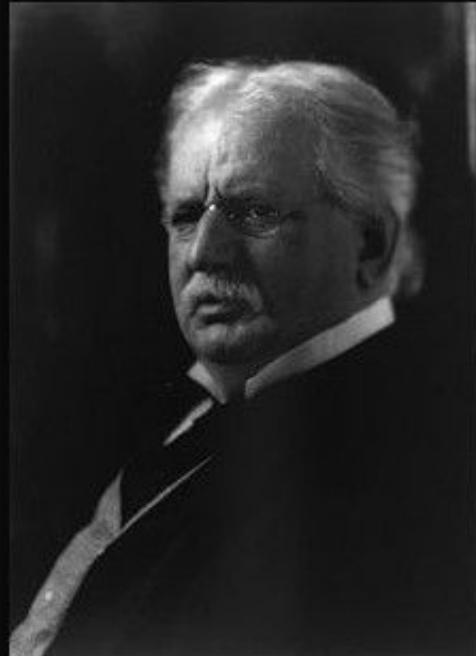
2 - Breakup of AT&T

3 - Impact on Research



# 1 – Regulated Monopoly

# 1 | Regulated Monopoly



Real difficulties can be overcome, it is only the imaginary ones that are unconquerable.

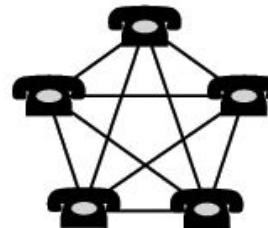
(Theodore N. Vail)

# 1 | Regulated Monopoly

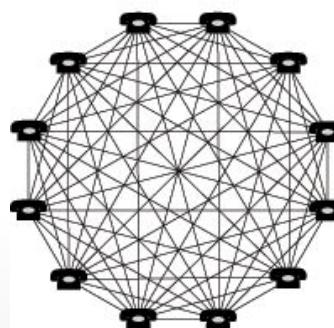
## Network Effect – Metcalfe Law



Cost = 1; Value = 1;

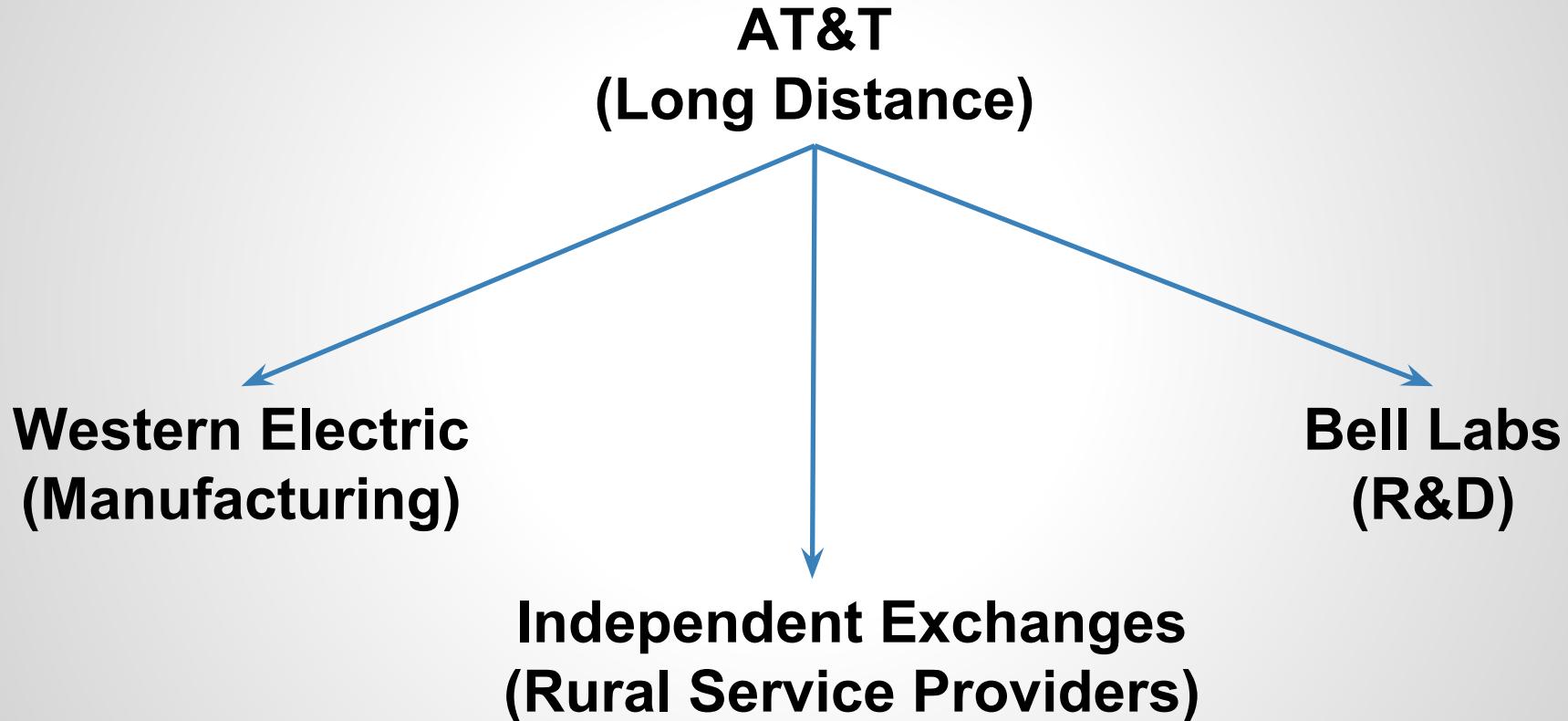


Cost = 5; Value = 25;



Cost = 12; Value = 144;

# 1 | Regulated Monopoly



## 2 – Breakup of AT&T

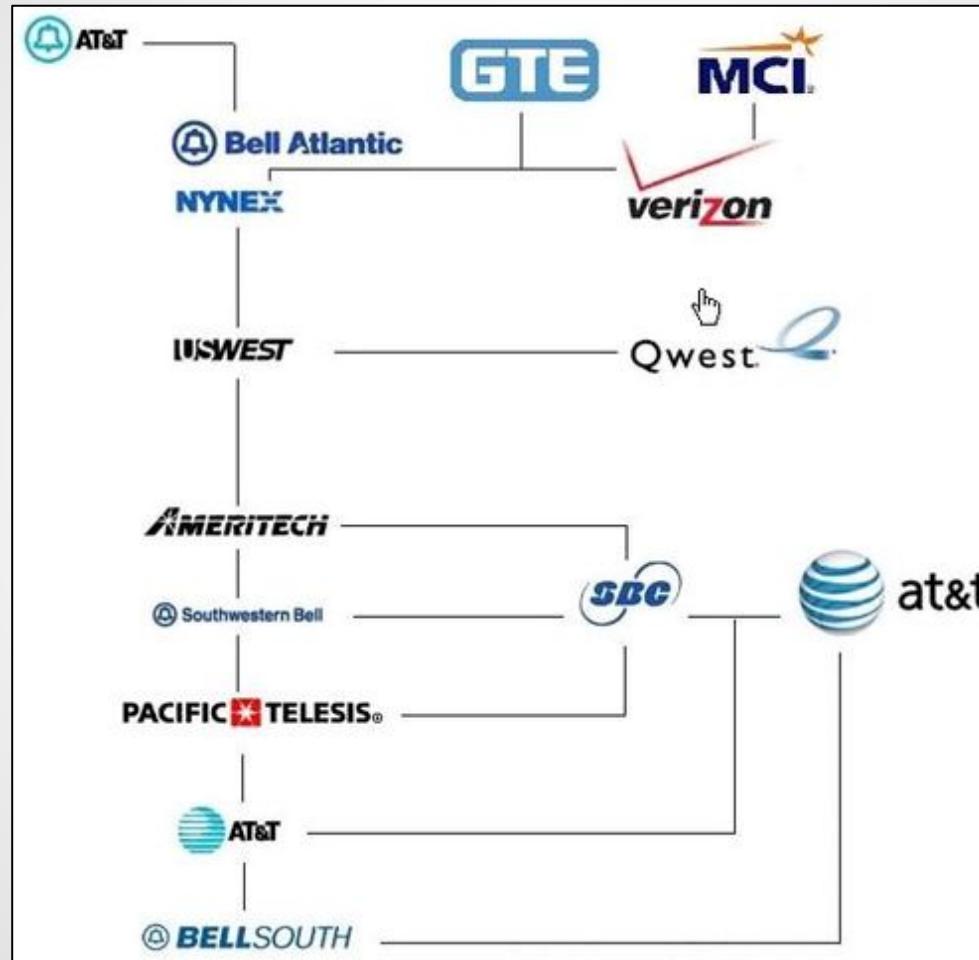
### Breakup of the Natural Monopoly

- 1914 Kingsbury Agreement – Long distance networks to independent exchanges
- 1921 Willis Graham Act – AT&T acquires more local companies

### Breakup of the Natural Monopoly

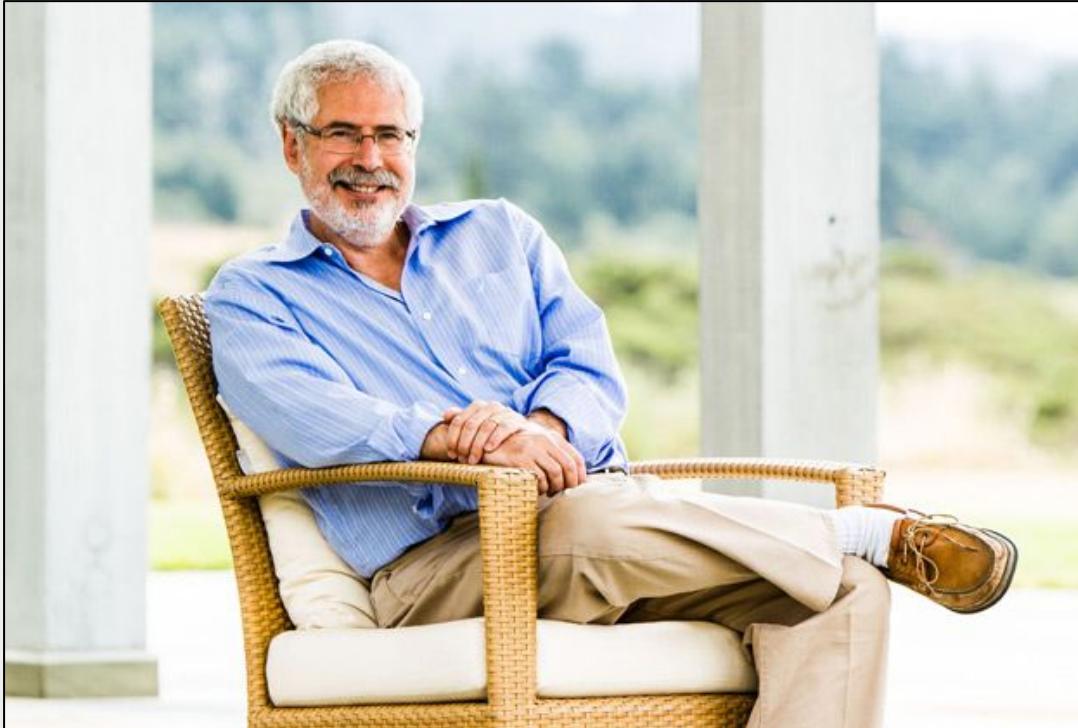
- 1949 Justice Department lawsuit on Western Electric – AT&T agrees not to get into computer business
- 1968 Carterfone – Other devices on the AT&T network
- 1974 Justice Department lawsuit – AT&T Divestiture in 1984.

## 2 | Breakup of AT&T



## 3 – Impact on Research

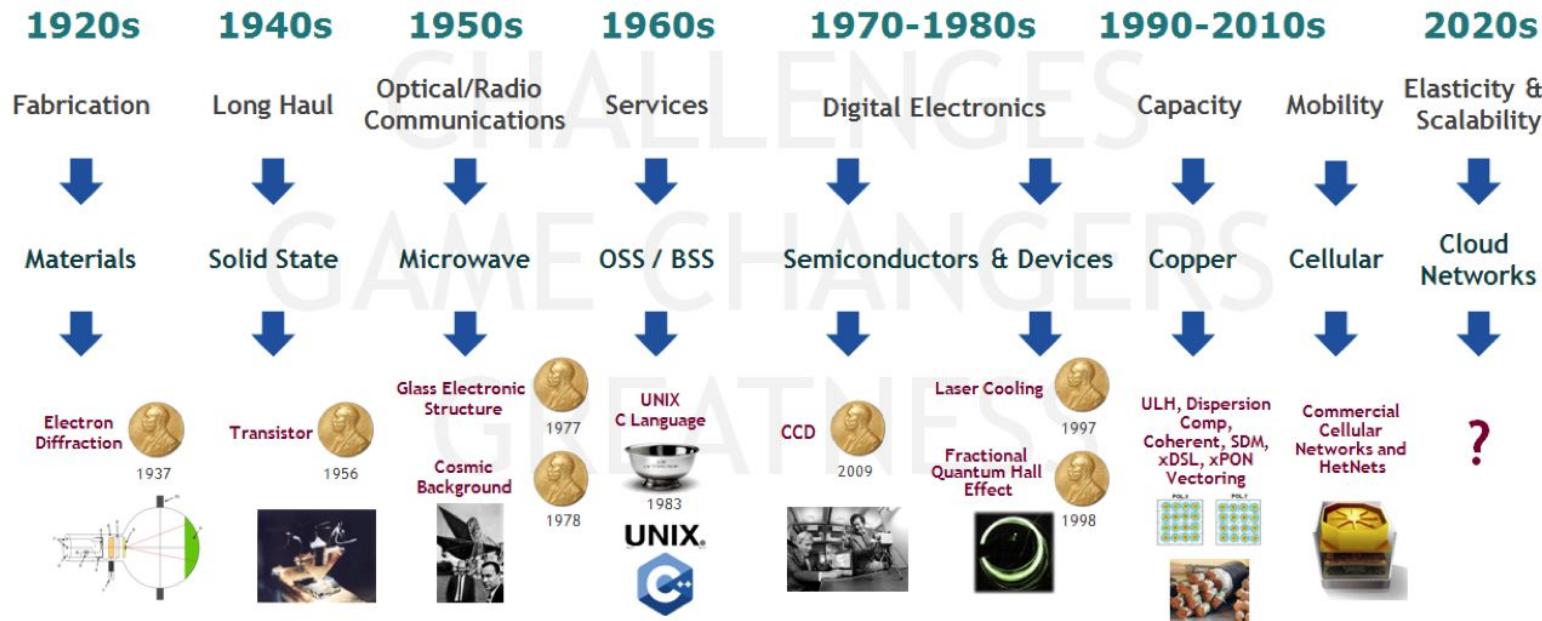
# 3 | Impact on Research



**The Success of a project is inversely proportional  
to the funds**

# 3 | Impact on Research

## BELL LABS: STILL INVENTING THE FUTURE



GREATNESS IN AND BY SOLVING REAL WORLD '10X' CHALLENGES