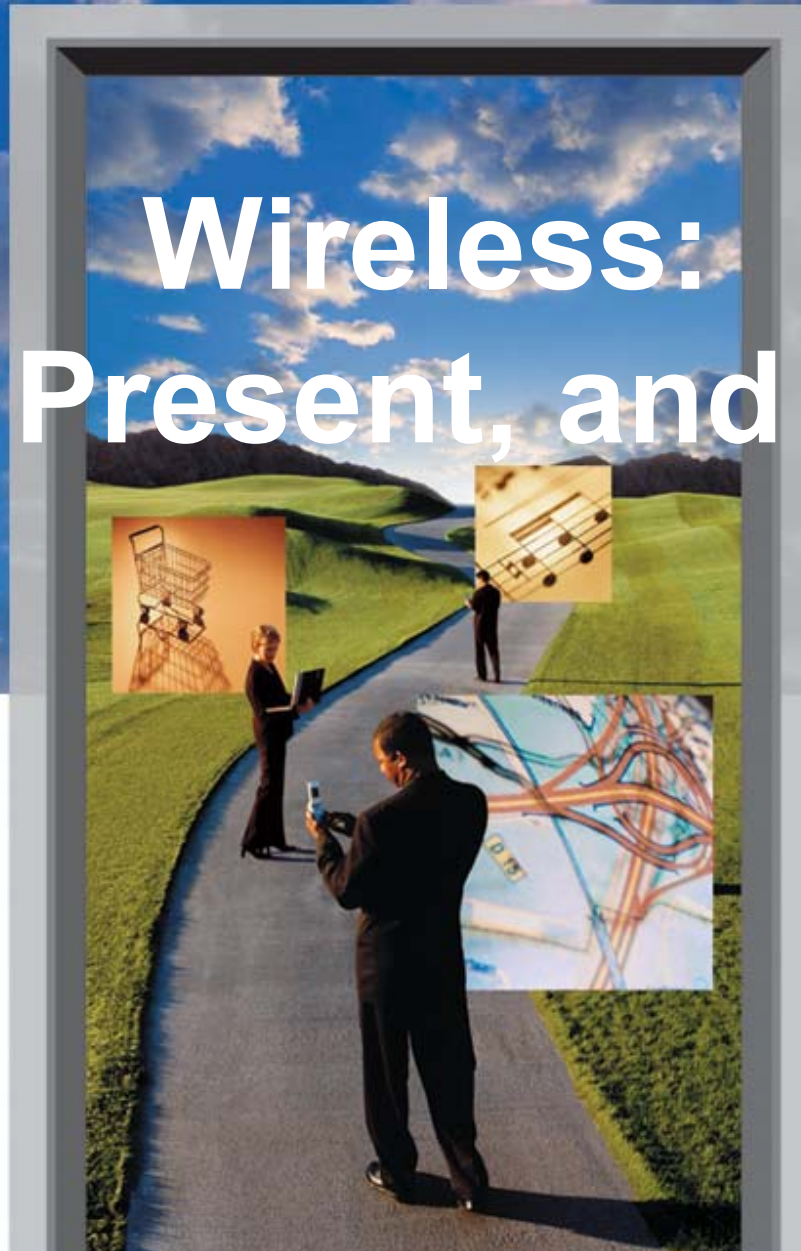




# Wireless: Past, Present, and Future



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June 2003



## When and how it all began...

- Over 100 years ago.
- It certainly didn't happen in any specific day but perhaps one day stands out.
- It was December 12, 1901...



**P.S. Cheating a bit...there is no original recording of the Morse code transmission from Poldhu, Cornwall to Signal Hill, Newfoundland. But probably sounded close to this.**

## Marconi after receiving the first transatlantic radio signal at Signal Hill, Newfoundland on Dec 12, 1901.



# The receiver looked like this:

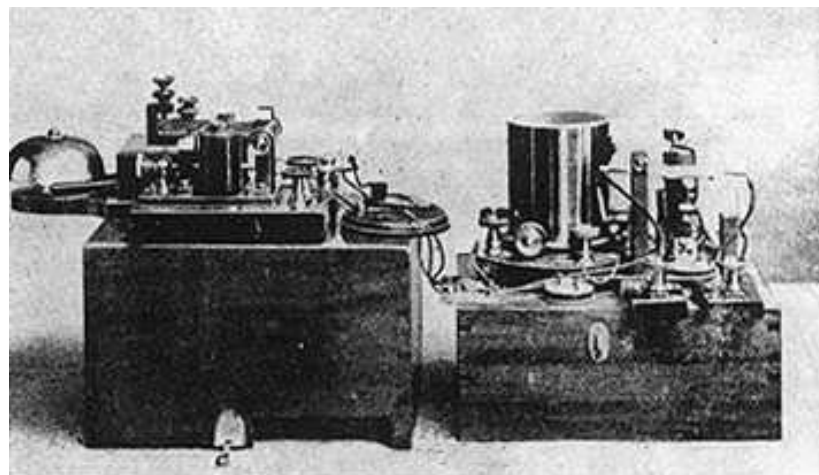


Fig. 4.

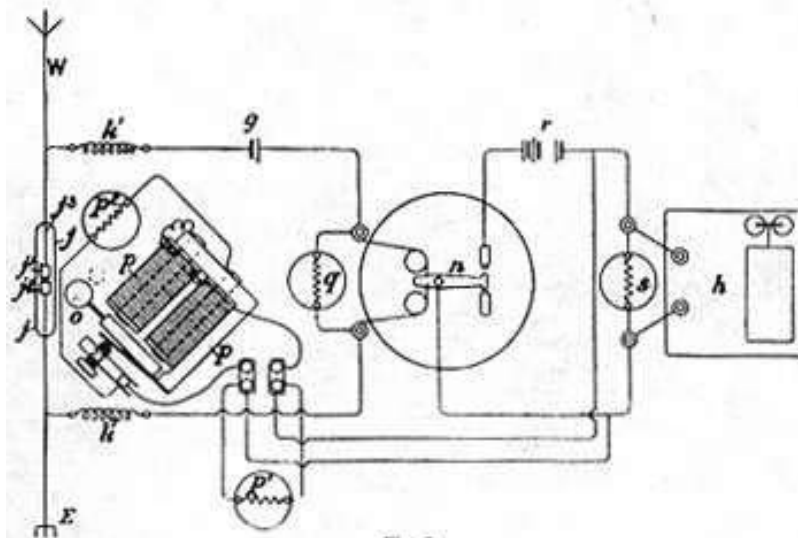
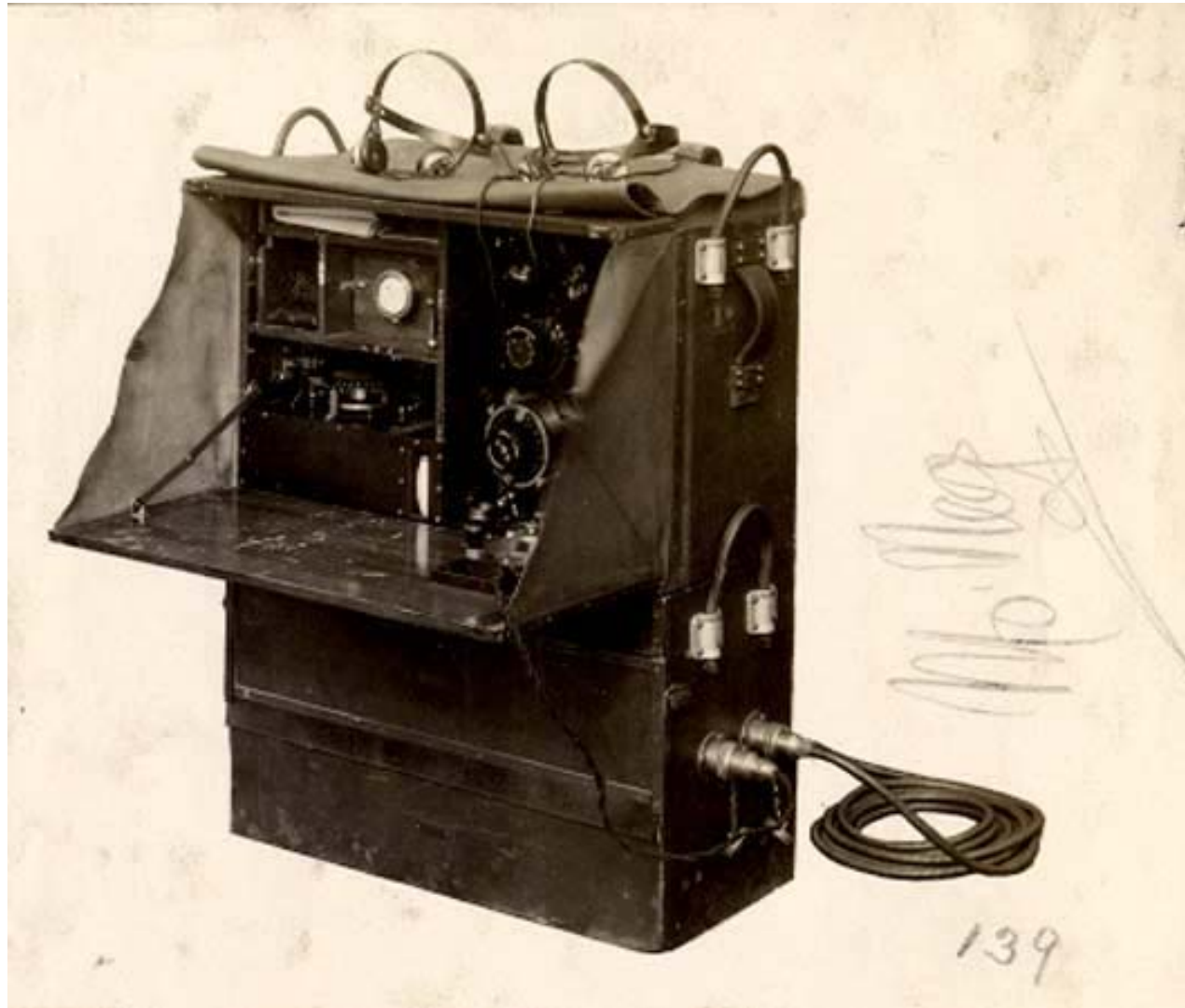


Fig. 3.

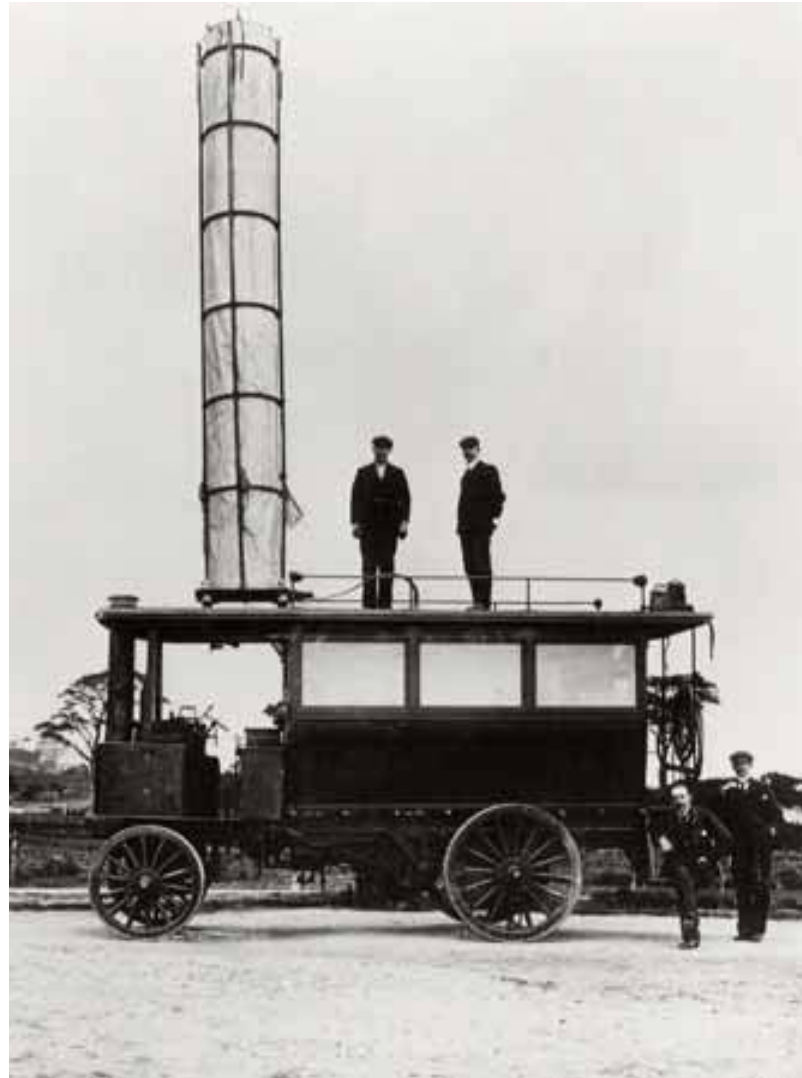
## No wires means mobility...early wireless pack (1915)



## Slightly more mobile...(1914-1918)



## Now we are talking mobile...(1917-1918)





## Let's jump ~10-20 years...

- **It must have been human nature, we want to communicate and we want to be untethered.**
- **1920's: AT&T develops first mobile radio communication system for emergency services (police, fire dept,...).**
- **1946: FCC grants the license for the first commercial service in St. Louis with a system developed by Bell Labs.**
- **Oh-oh, big problem! Only six simultaneous voice conversations.**
- **What to do?**



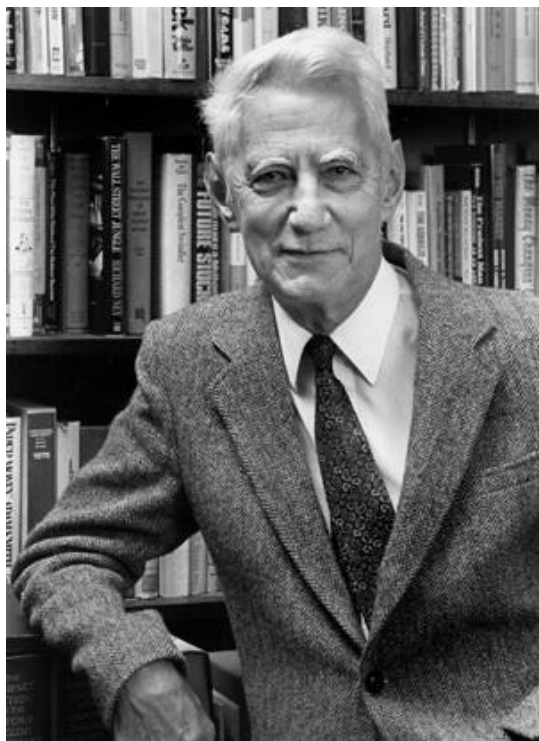


## The “cellular” concept (Bell Labs, circa 1947)

- **Divide a geographical area (e.g. a city) into “small cells” each with its own radio tower. Assign some frequencies for transmission to each cell and reuse those frequencies in cells that are enough “far apart”. As the user moves from cell-to-cell, the conversation is “handed off” from one frequency to another.**
- **Quite brilliant.**
- **In 1947, AT&T petitions the FCC to assign a reasonable amount of spectrum for a commercial system based on the “cellular” concept.**
- **The first cellular commercial system goes live in Chicago...oh well, it is now 1983.**



In the meantime (1947-48) a couple of things happened at Bell Labs...



**Claude Shannon**

***Information Theory***



**John Bardeen  
William Shockley  
Walter Brattain**  
(left to right)

***Transistor***



## ***Claude Shannon and Information Theory***

- **Claude Shannon in his famous paper of 1948 addressed all the key questions in communications.**
- **Everything is bits (David Tse UC Berkeley):**
  - Any information source has entropy  $H$  bits/sec
  - Any channel has capacity  $C$  bits/sec
  - Reliable communication can occur if and only if  $H < C$
- **Wow ! At the beginning most people didn't understand what he was talking about. Especially since he didn't tell us how to design the optimal system.**
- **Today, practically every communication system is designed according to the principles of Information Theory.**



## A first lesson

- **“Averaging is good, and smart averaging is better.”  
(Dr. Andrew Viterbi)**
- **A signal of duration  $T$  sec and bandwidth  $W$  Hertz contains  $N = 2TW$  nearly independent dimensions.**
- **Shannon showed us that we can make bit errors “disappear” as long as we transmit less than**
- **$\frac{1}{2} \text{Log}_2(1+P/N)$  bits/dimension**
- **The smart way to do it is to aggregate a whole bunch of bits and have them collectively modulate all the dimensions, effectively averaging over all independent dimensions.**
- **We refer to this “smart averaging” as error correcting coding.**

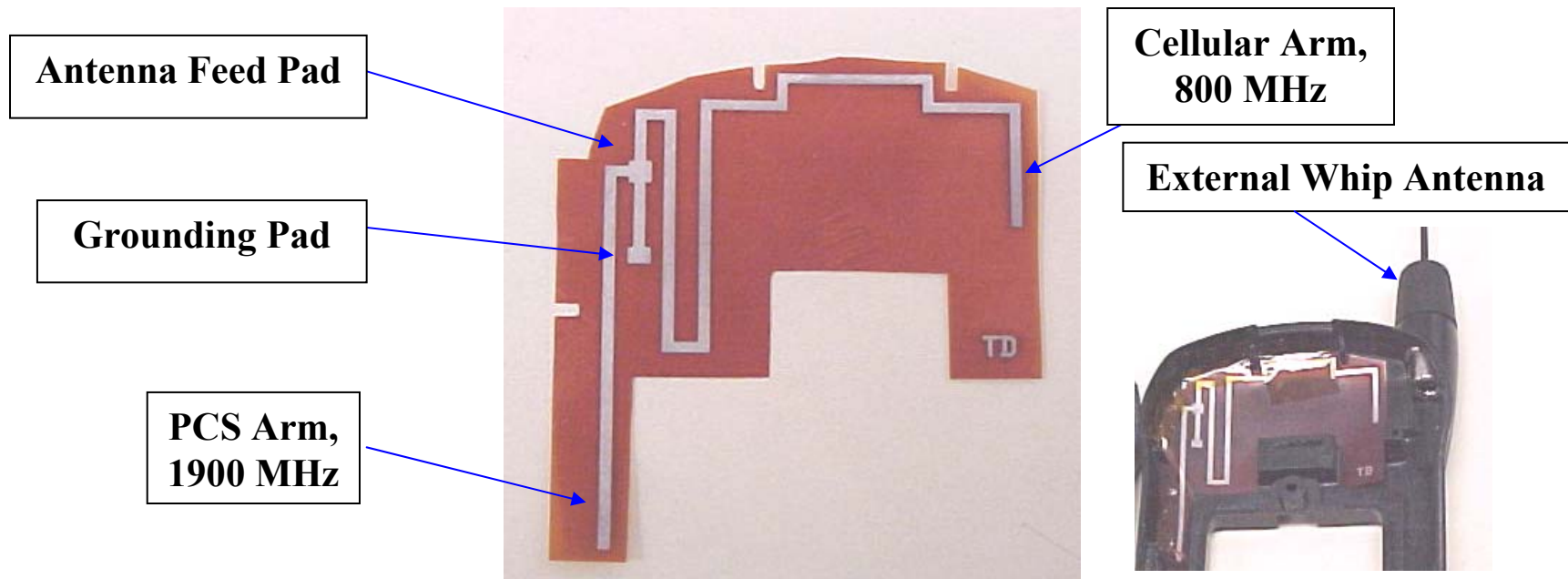


## More on the first lesson

- **Since dimensions are proportional to bandwidth and spectrum is finite, can I “create” more dimensions to increase my smart averaging?**
- **The answer is yes, you can create “spatial” dimensions by using multiple antennas.**
- **Now I can average both spatial and spectral dimensions.**

## Rx diversity

- Two antennas and two receivers in the phone.
- 50 times as much voice traffic as analog systems in the same amount of spectrum with cdma2000 1x.
- Increased Data Throughput





## A second lesson

- **When communicating in the presence of interference the best strategy is to have both signal and interference to appear as wideband noise.**
- **Thus the solution is spread-spectrum: CDMA**



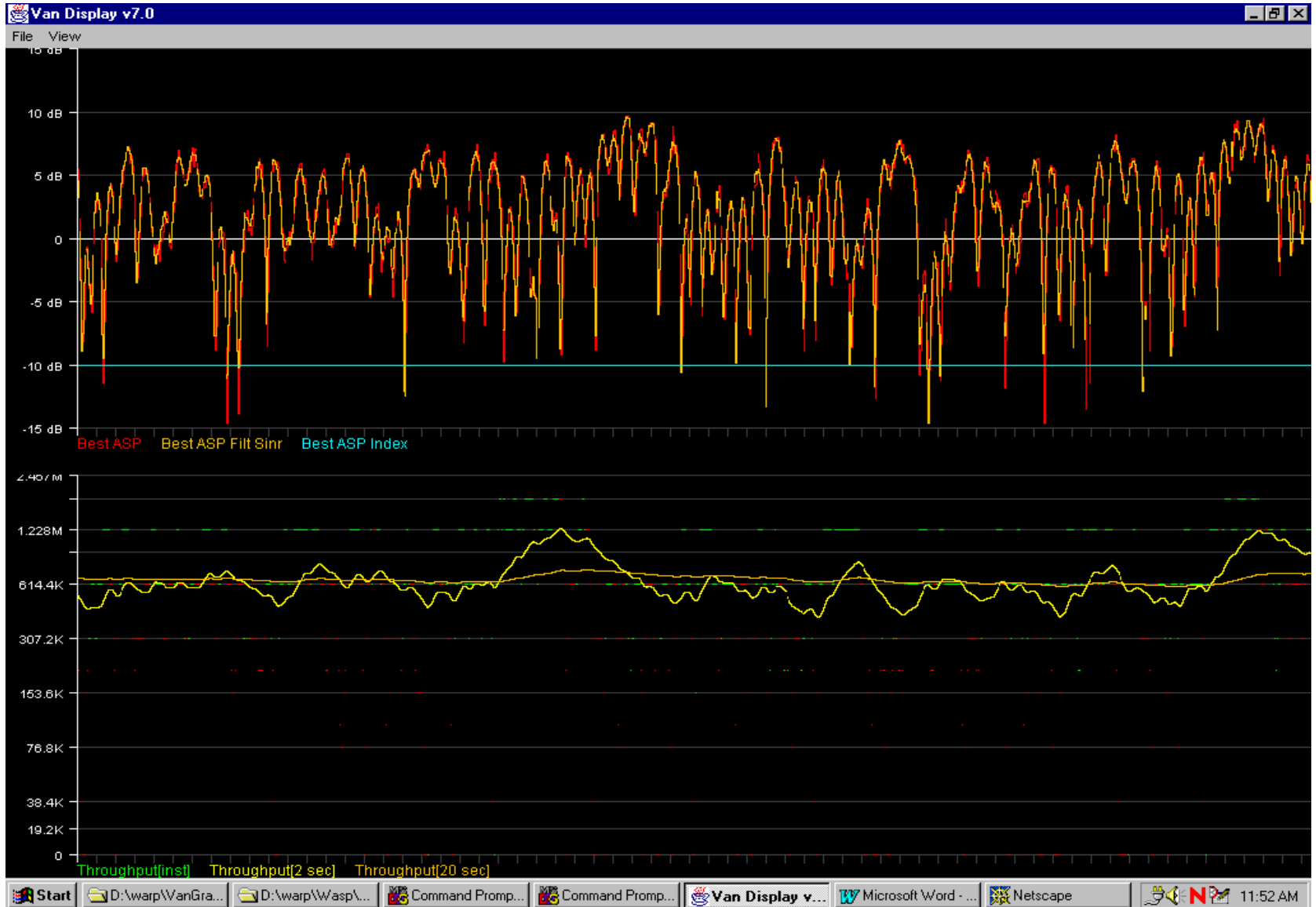
## **A third lesson: Smart averaging is good, smart scheduling is great.**

- **The traditional view of wireless system designers is that fading is bad.**
- **The modern view is that fading is GOOD, and we can take advantage of it.**
- **It is now universally called Multi-User Diversity and was first introduced in cdma2000 1xEV-DO systems.**



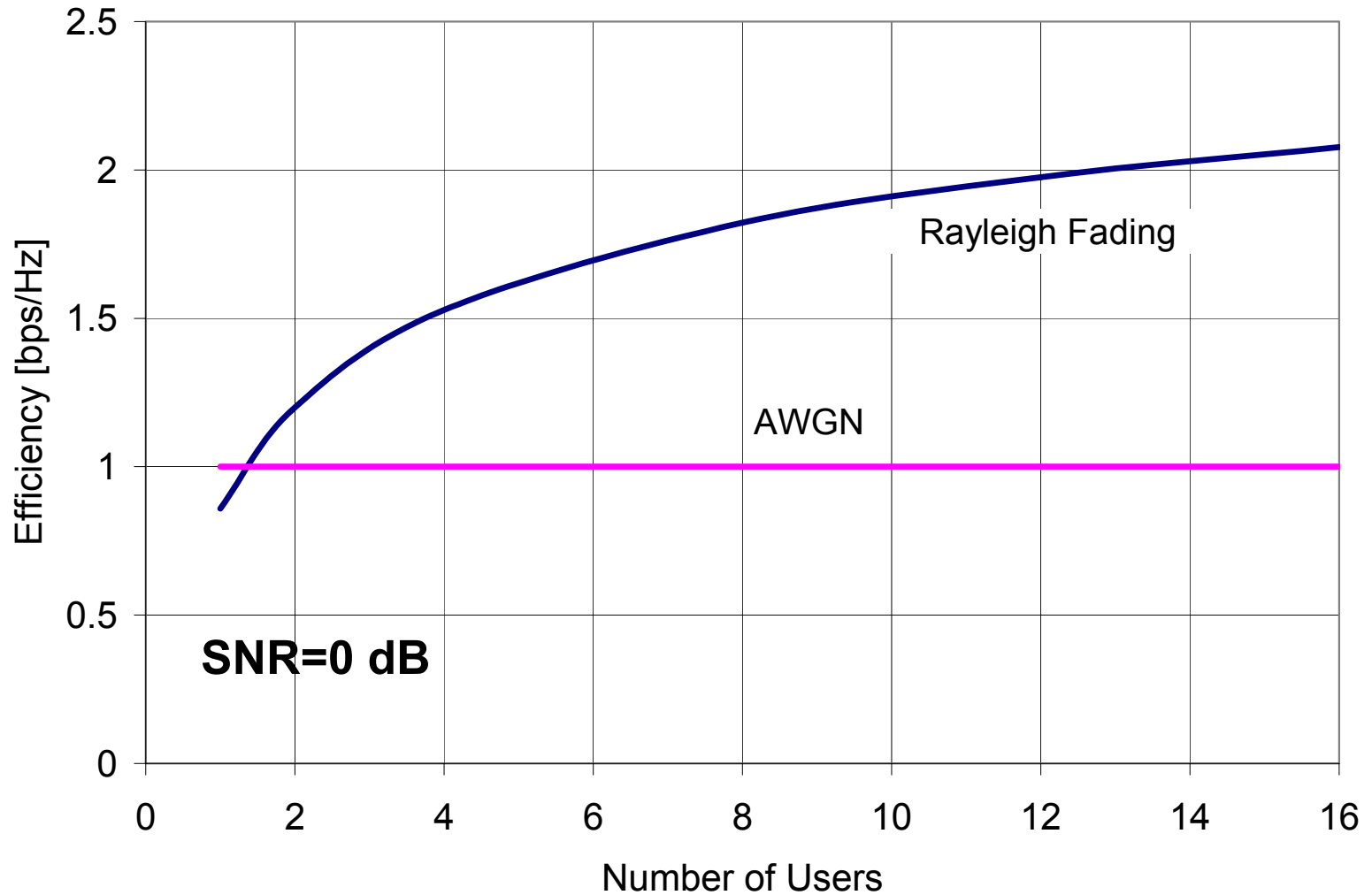


# Fading





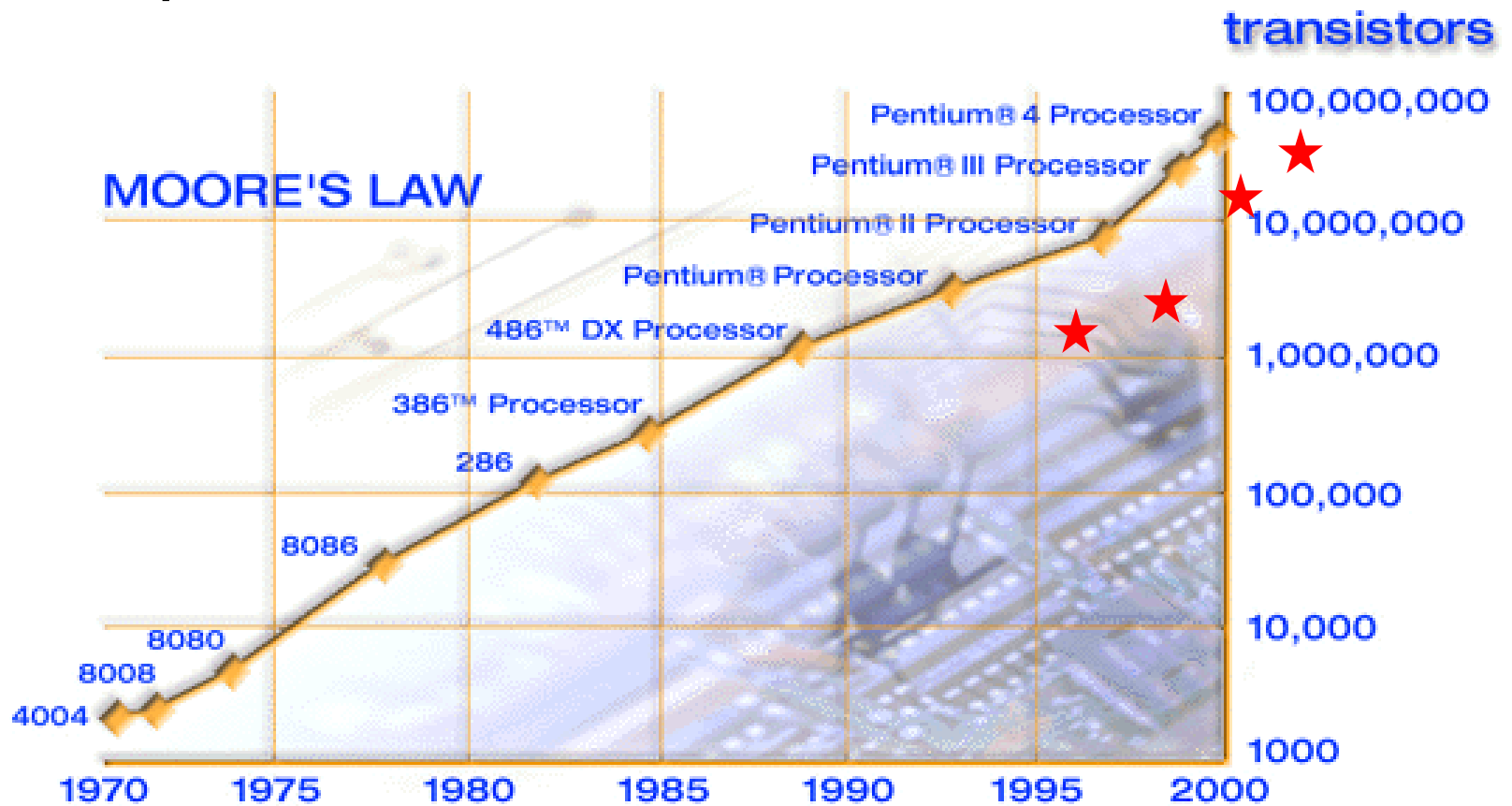
# Multi-User Diversity





# Implementing the lessons

## ★ Cell phones IC's



Moore's Law graph from Intel



## Some closing thoughts about the future...

- **We will learn more lessons.**
- **Once we provide wide-area, cost-effective, and high-speed connectivity to wireless devices the applications are limitless.**
- **“If you want to see the future, or at least get a taste of it, South Korea is the place. They have these tremendous EV-DO networks there, people flip open their phones and get real time video feeds from various intersections around Seoul to check out the traffic, they can get live news sent to their phones...”**  
**(interview with CISCO, May 2003)**

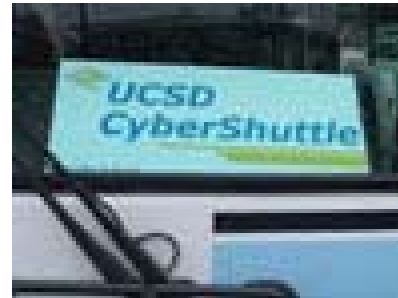


## Traffic check...



# UCSD CyberShuttle

- UCSD 1xEV-DO Test Site
- Cyber Shuttle
  - Cdma2000 1xEV-DO to moving bus
  - 802.11b distribution within bus
- Regular campus and off-campus service



# UCSD Stroke Center Clinical Study

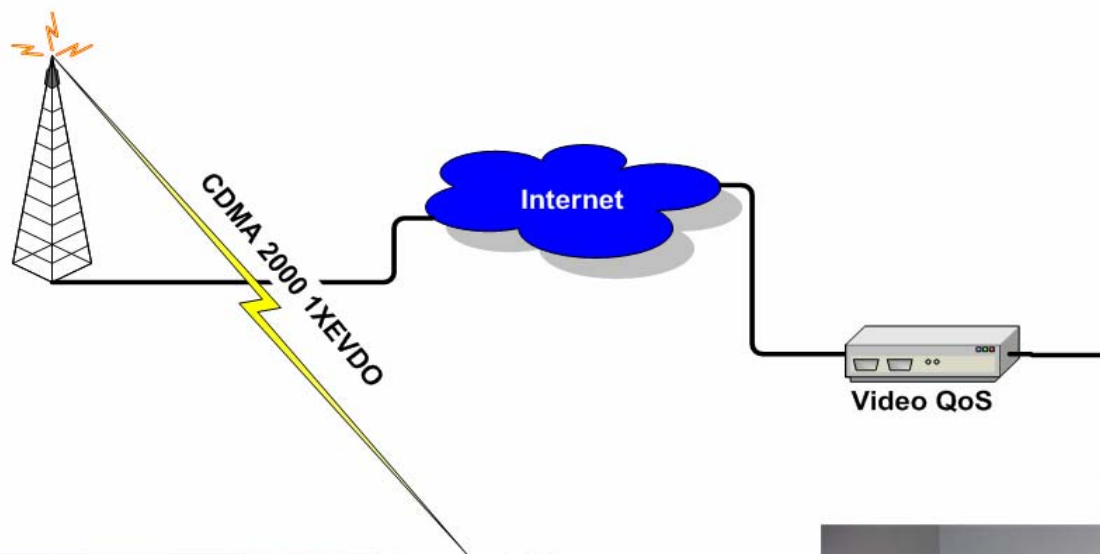
## Dr. Pat Lyden, Director

- **Need: Diagnose and treat stroke victims**
- **Special circumstances**
  - A few trained specialists
  - Narrow window of opportunity for intervention < 3 Hrs.
  - Stroke patients may be at remote locations
- **Solution**
  - High resolution, low jitter video diagnosis tool
    - End-to-end QoS management
  - Video delivered over CDMA 2000 1x EV-DO to specialists
    - Viewing station –standard laptop with 1xEV-DO modems



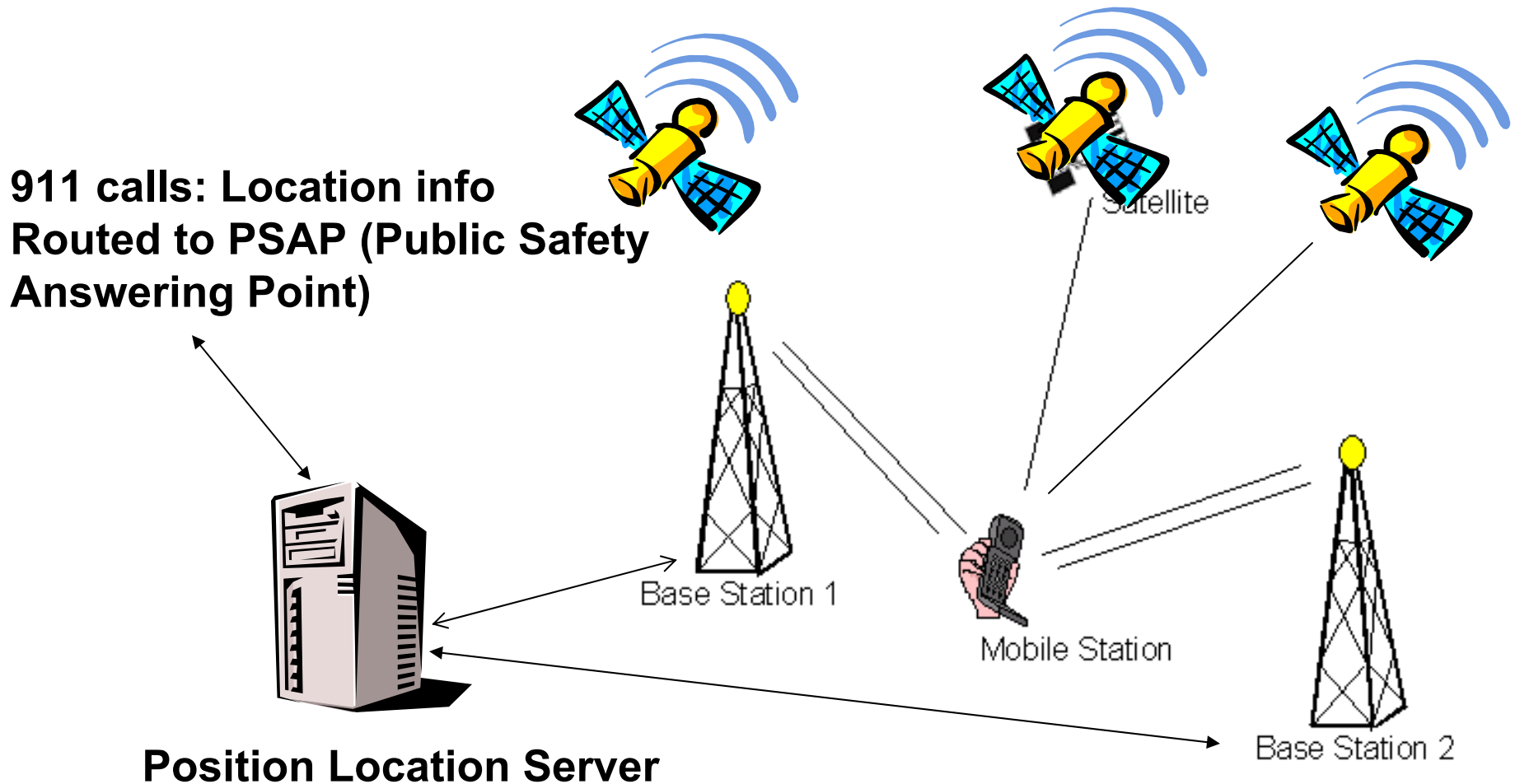


# UCSD Stroke Center Setup



# Position Location – Assisted GPS

- In 2001, in the U.S. 57 Millions 911 calls were placed from cell phones



## Will it look like this?



From Motorola concept phone web page