

# Evolution of Communication Systems

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# Outline

- telephony from history toward future
- classification of individual generations, principles of switching
- problem of complexity in space switching
- principles of time switching
- telephony as an application (VoIP)



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# From history

- instead teleph. exchange we use expression Communication System/Server nowadays
- modern telephony is result more than 100 years of evolution
- differences between narrow-band, wide-band and ultra-band telephony
- amazing story about telephone invention, actors: A.G. Bell, E. Gray and A. Meucci



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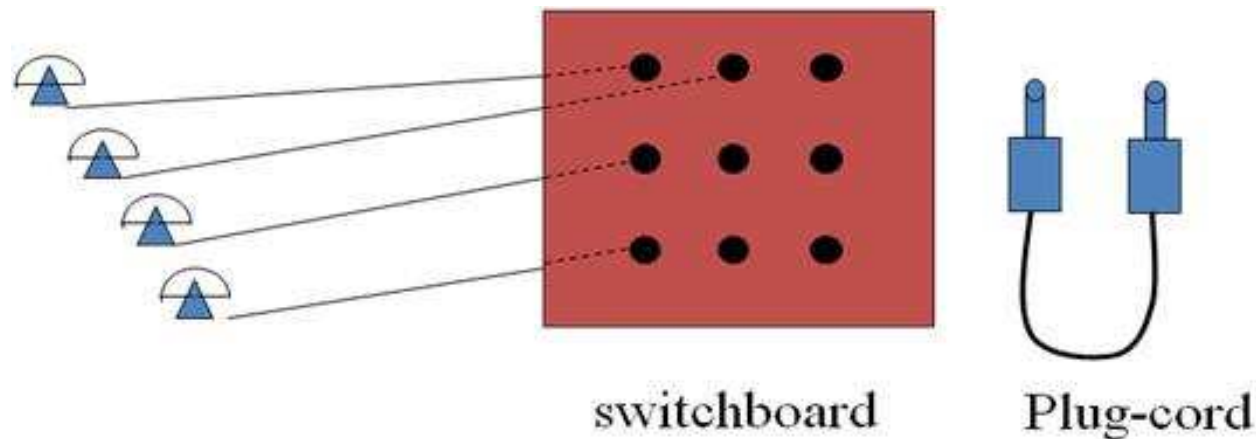


# **Students developing WiFi IP phone** (they could use components with overall price < 50 USD)

- they selected RouterStationPro
- impl. under linux OS OpenWRT

# Generations of switching systems

- 1876, Bell gained unbelievable publicity at exposition in Philadelphia
- 1878, the first teleph. exchange in Connecticut, with manual switching in switchboard



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# Generations of switching systems

1<sup>st</sup> generation, **Strowgers** Switch

2<sup>nd</sup> generation, **Crossbar** Switch

3<sup>rd</sup> generation, **SPC** (Stored Programme Control)

4<sup>th</sup> generation, **Time switch** (TDM)

5<sup>th</sup> generation, **Softswitch** (packed based  
switching in IP Multimedia Subsystems)



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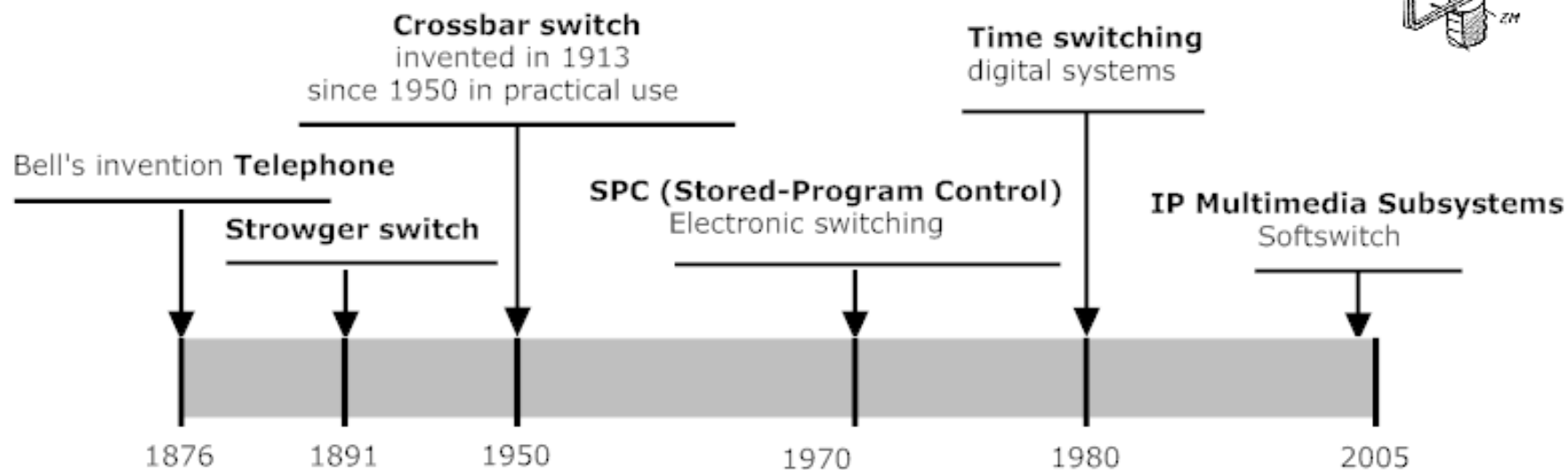
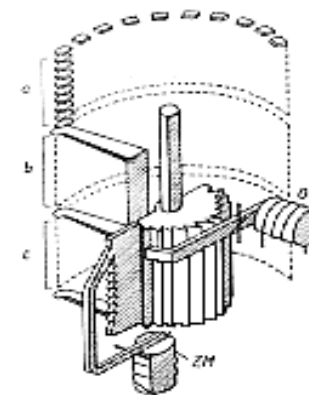
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# Strowger switch

- 1891, grave digger A. Strowger inveted electromechanical step-by-step switch, **Strowger switch**, included in 1<sup>st</sup> generation
  - Step-by-Step (stepping selector)



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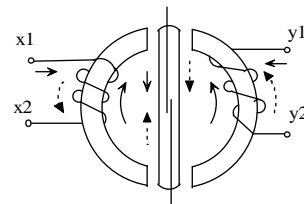
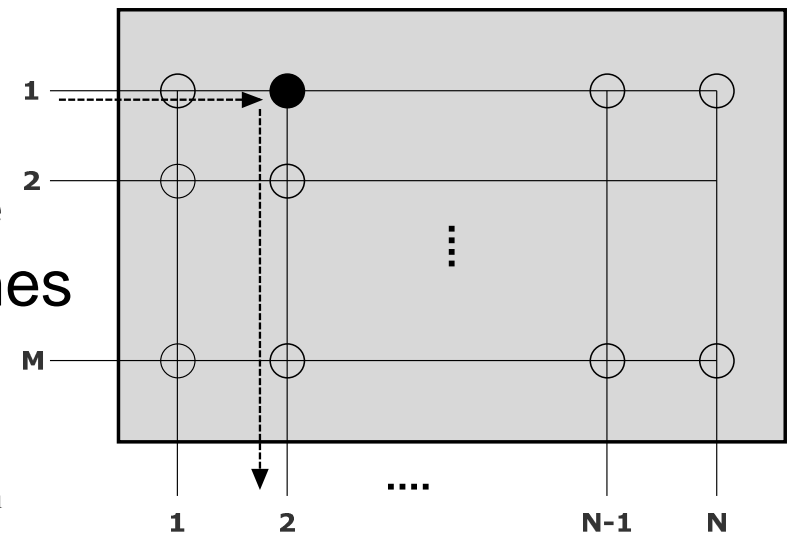
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# Crossbar (Space switching)

The crossbar switch is an electromechanical switch with a matrix of vertical and horizontal bars and simpler motions that worked more reliably than Strowger switch

The crossbar switch is an assembly of individual switches between multiple inputs and multiple outputs. The switches are arranged in a matrix.



Ferreed switch

Switching in junctions

- ferreed switch in beginning
- lately semiconductors



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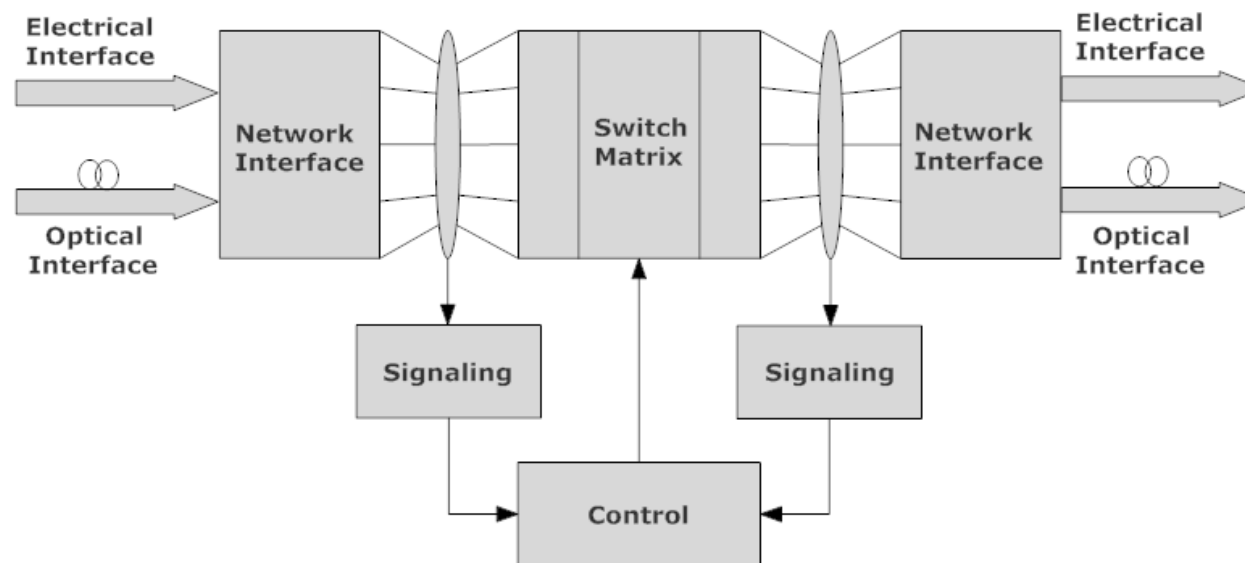
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# SPC

## SPC, **Stored-program Control**

CPU, digital control but with **space switching**



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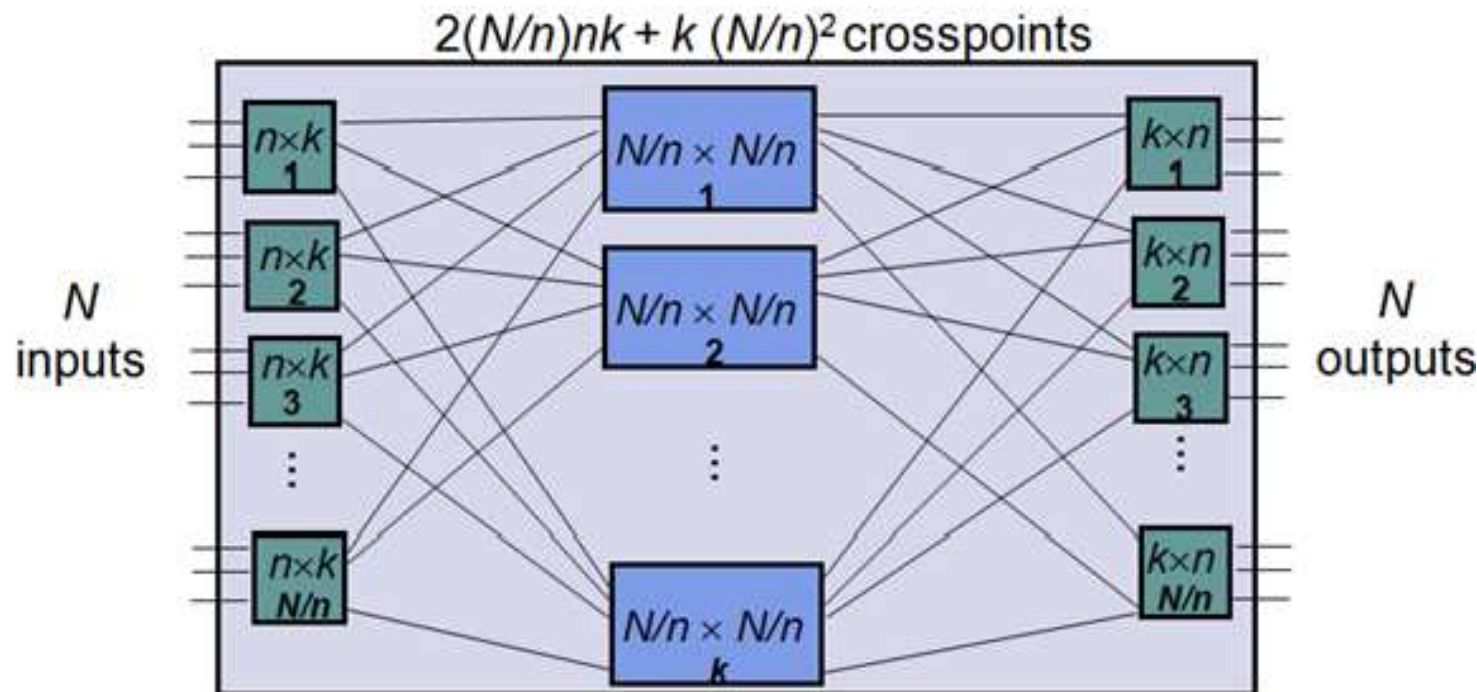
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# Problem of complexity in switching

Issue of complexity in switching matrix, **usually 3-stages**,  $N$  inputs,  $N/n$  elements in 1<sup>st</sup> and in 3<sup>rd</sup> stages,  $k$  elements in 2<sup>nd</sup> stage, crosspoints  $C(n)$



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# Complexity in space switching

Clos non-blocking condition

$$k \geq 2 \cdot n - 1$$

crosspoints from previous slide

$$C(n) = 2Nk + k \cdot \left(\frac{N}{n}\right)^2$$

and expressed with Clos condition

$$C(n) = 2N \cdot (2n - 1) + (2n - 1) \cdot \left(\frac{N}{n}\right)^2$$

min. complexity, derivative is zero

$$0 = \frac{dC(n)}{dn} = 4N - \frac{2N^2}{n^2} + \frac{2N^2}{n^3} \quad n \approx \sqrt{\frac{N}{2}}$$

then for  $n \gg 1$

for  $C(\min)$  
$$C_{\min} = \left(2N + \frac{N^2}{\frac{N}{2}}\right) \cdot \left(2 \cdot \sqrt{\frac{N}{2}} - 1\right) = 4N \cdot (\sqrt{2N} - 1)$$

simplified

$$C_{\min} \approx 4N \cdot \sqrt{2N}$$



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## Example: a design of non-blocking switch with minimal complexity, inputs N=512

$$n = \sqrt{\frac{512}{2}} = 16 \quad \text{then } N/n \text{ elements } 512/16=32$$

**32 elements in 1<sup>st</sup> stage**

Every element will be equipped with **16 inputs**

Clos condition says:  $k=2*16-1=31$

**31 elements in 2<sup>nd</sup> stage**

Complexity - overall number of crosspoints  $C=63488$



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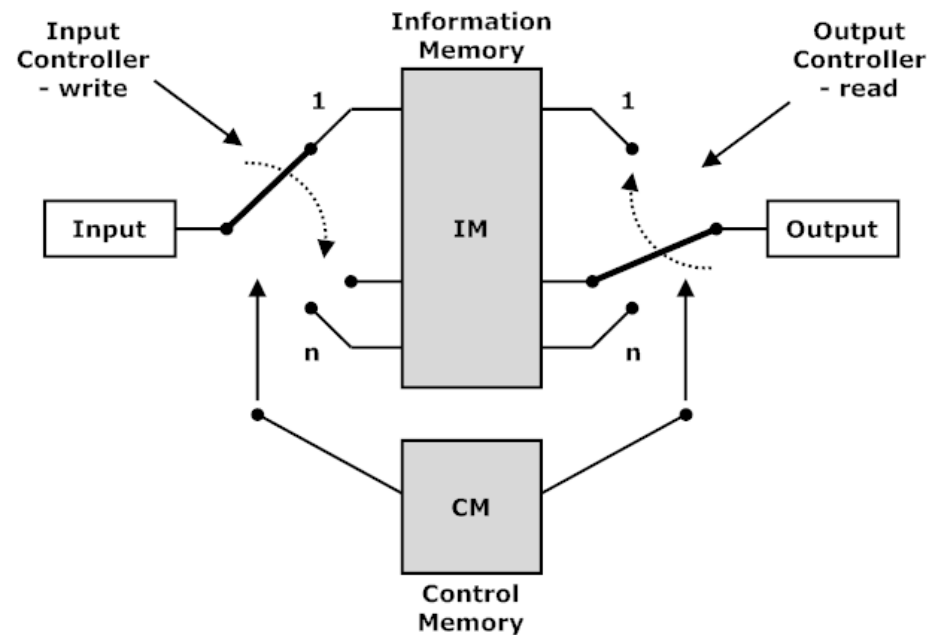
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# Time Switch

**Time switching**, key condition for 4<sup>th</sup> gen.

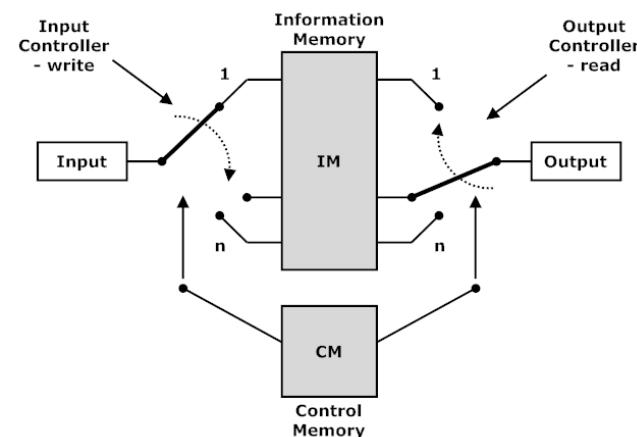
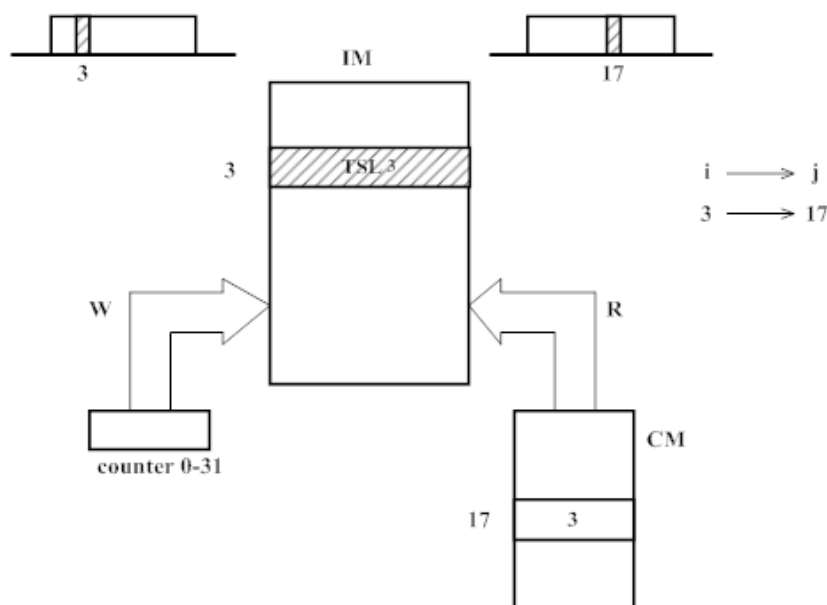
time switch is able  
to change Timeslot  
of individual bits  
(mostly 8 bits word)



# Time Switch

Tr - switch

Input	Output	type of T-switch
Synchronous writing	Asynchronous reading	Tr
Asynchronous writing	Synchronous reading	Tw
Asynchronous writing	Asynchronous reading	Twr
Synchronous writing	Synchronous reading	Does not make sense



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# Softswitch

- IP telephony, VoIP – new approach, telephony is an application in IP

which application protocols are needed?

- for signalling: mostly **SIP** (Session Initiation Protocol), RFC 3261
- for media: **RTP** (Real-Time Protocol), RFC 3550, or **SRTP** (Secure RTP) RFC 3711



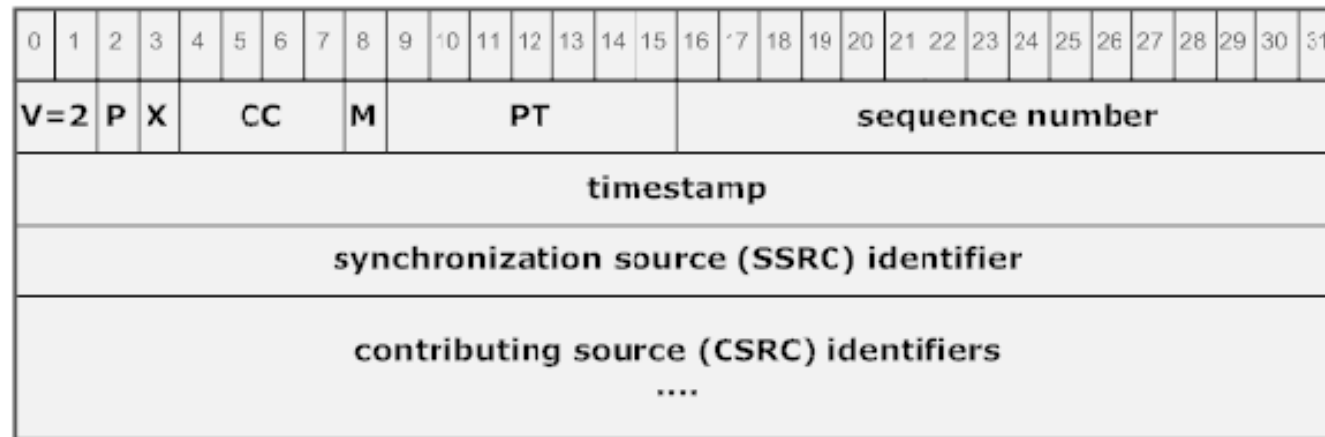
# Real Time Protocol

- TCP vs. UDP, transport layer
- RTP is based on UDP
- + timestamps and sequence numbers



# Real Time Protocol

- payload type identifies the media type

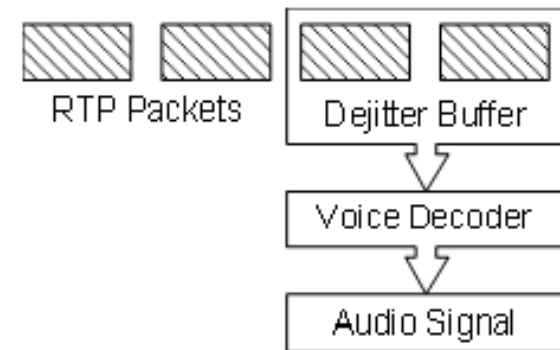
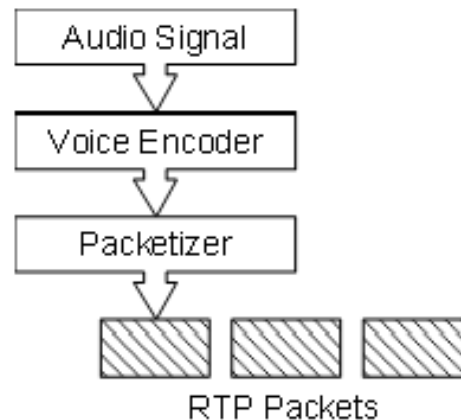


- RFC 1889, 1996 (Transport Protocol for Real-Time Applications)



# Audio from Sender to Receiver

- audio signal, coding
- packetizing
- Transmission



- timing impairments - > jitter
- de-jitter buffer, elimination
- and decompression



# Audio from Sender to Receiver

increasing bandwidth requirements caused by overhead

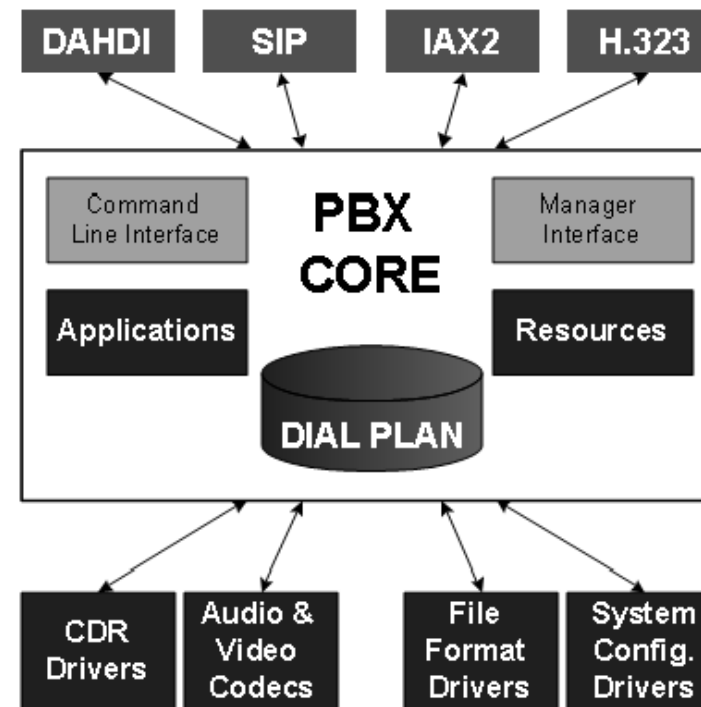
- G.711, cca 90 kbps (from 64kbps)
- GSM FR, cca 40 kbps (from 13 kbps)
- G.729, cca 35 kbps (from 8kbps)
- G.723.1, cca 25 kbps (from 5.3 kbps)



# Softswitch open-source project Asterisk

*"I was so excited the first time I got a phone call delivered through my PC using my own software."*

*Mark Spencer*



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# Thank you for your attention

## Q&A



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