TIMING IN TELECOMS

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Agenda

- 19^{th} Century
- Early 20^{th} Century
- Bit of a gap
- Later 20^{th} Century
- 21^{st} Century

Digital came first

Early telecom cable infrastructure was lossy, noisy and had bandwidth limitations.

This made analogue voice transmission challenging over long distances.

The robustness of a digital system is better suited to this environment.

Many telegraph systems appeared in the mid 19th century including alphabetical printing machines.

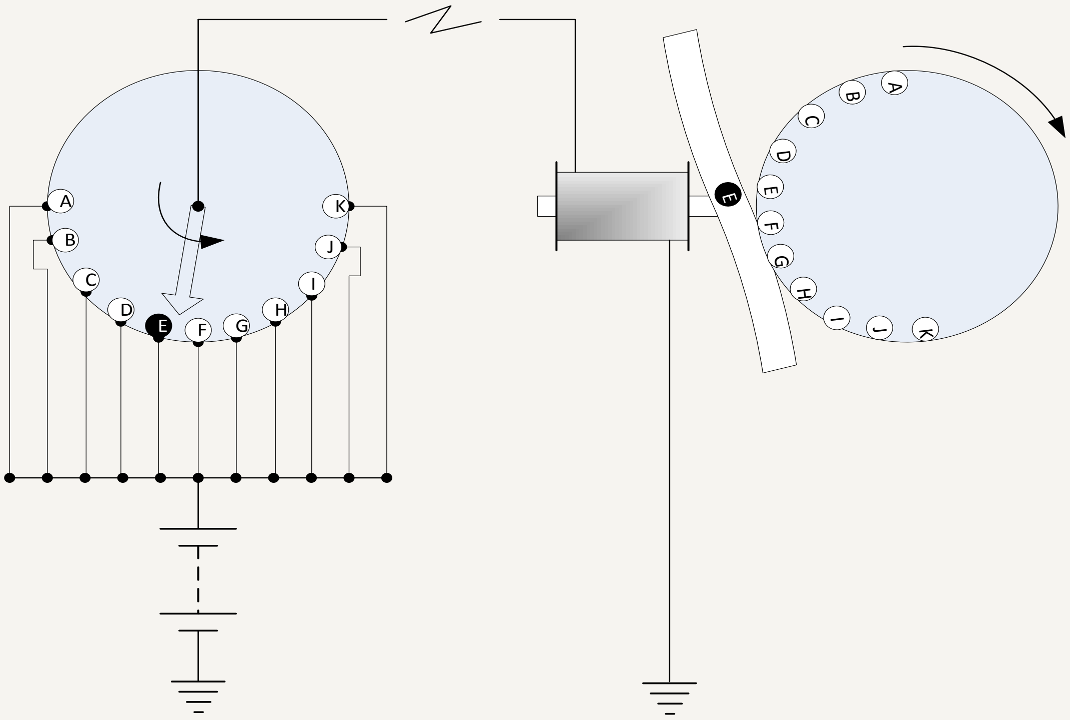
Anatomy of an alphabetical printing telegraph

A rotating selector passes each letter in turn.

Where a letter is actuated by the operator, the selector closes the circuit sending a current pulse to the far end.

At far end An electromagnet responds and stamps a letter from a rotating wheel onto a paper strip.

The selector and the letter wheel must be synchronised, frequency and phase.



Frequency and phase synchronisation

Precise frequency reference operating independently at each end (plesiochronous).

Phase alignment device. An initial pulse starts the rotation of each machine at the same point.

Thereafter, synchronisation relies on both machines running at the same speed (phase synchronisation holdover).

Telephony takes over

Printing telegraphs evolved, improved, and became more common.

But cable technology improved (with hard drawn copper and loading coils), voice transducers improved, and long distance analogue voice became practical.

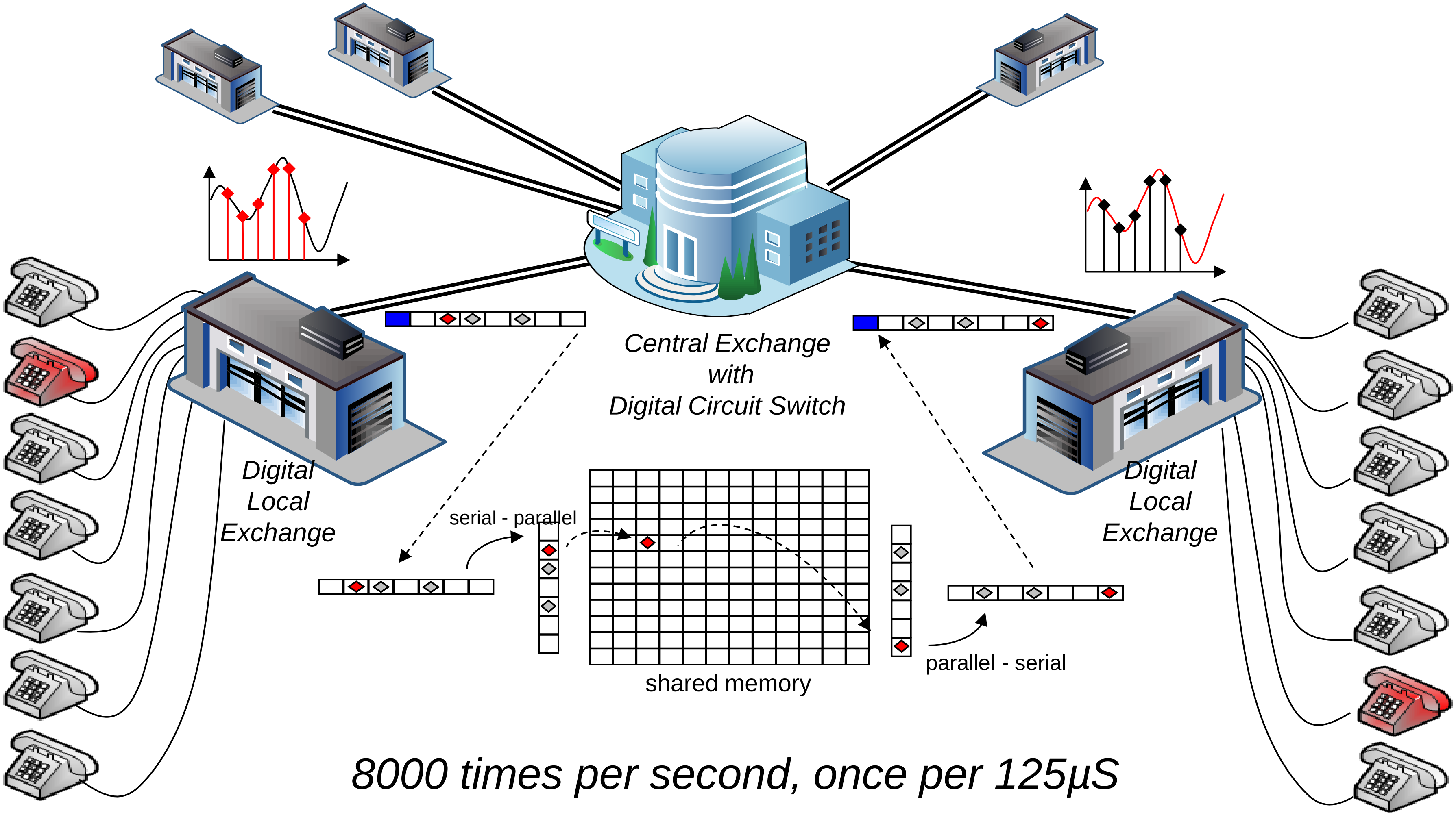
Telephony became dominant, (and didn't need synchronisation).

Alexander Graham Bell in 1892.
Gilbert H. Grosvenor Collection, Prints and Photographs Division, Library of Congress.

Fast Forward...

...to digital circuit switched telephony.

*Not mentioning analogue frequency multiplex carrier alignment. Is this synchronisation? FBD (for bar discussion).



Martin Kingston, Journal of the Institute of Telecommunications Professionals.

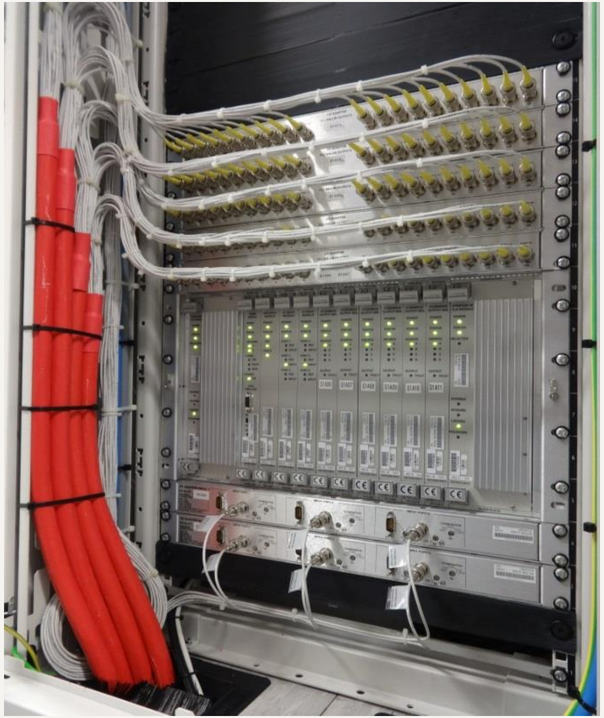
Synchronisation is dead,

Circuit switched telephony, and the transmission multiplexing techniques associated with it, drove synchronisation as we know it in the second half of the 20th Century.

But IP telephony and soft-switching began to replace circuit switched telephony, and packet transport began to replace multiplexed transmission.

The beginning of the end of the need for synchronisation?

No. A new user had quietly taken advantage of existing synchronisation for a different purpose…



Cellular base stations take a free ride,

Digital cellular base stations control carrier frequency and frame rates so that a mobile device can decode signals from many nearby base stations and seamlessly move between them during calls.

Early base stations achieved this using high stability oscillators, however the transmission to these base stations was the same Primary Rate signal as used in digital telephony.

The accurate frequency reference carried along with this signal was soon adopted for use by the base station.

Long live synchronisation!

Cellular systems requirements are actually significantly less demanding than digital telephony.

A de-facto standard developed. A transmission feed with a long term frequency accuracy of 15ppb and jitter within the bounds set for a PDH transmission interface is acceptable.

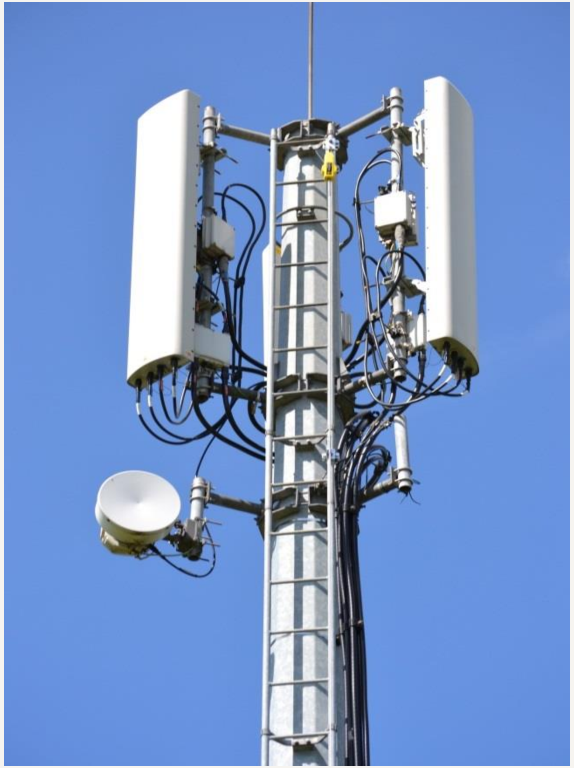
Primary Rate transmission continued to be used for base stations from 2G (TDM) through to 3G, but eventually base stations adopted packet transport (mandatory for 4G and now common for 3G and 2G). Usually Ethernet based, this created a challenge for synchronisation which has been addressed in several different ways.

The next step

Some cellular base station air interface technologies require alignment in time as well as frequency synchronisation.

This has been the case for some time where a Time Division Multiple Access (TDMA) scheme is being used with the same spectrum serving both uplink and downlink, but new technologies in LTE-Advanced have brought particularly strict requirements.

Some scenarios demand sub-microsecond time alignment of base station transmissions



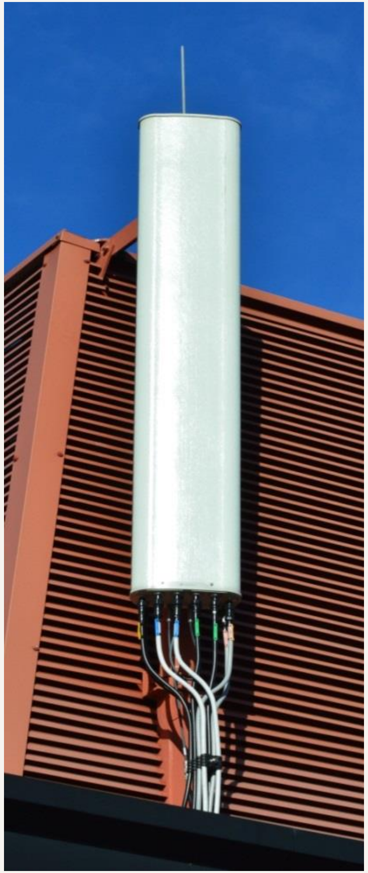
LTE-Advanced Synchronisation

- Current mobile network technologies in the UK operate with the same level of synchronisation as used since the dawn of GSM!
  - Frequency 15ppb with G.823 traffic mask
- The first new requirement for 20 or so years will be phase synchronisation, supporting new services and increased capacity density in 2016/2017.
  - eMBMS and eICIC
  - TDD
  - Phase +/- 1500nS

From LTE-Advanced to 5G

LTE-Advanced features include:

- eMBMS
- Downlink Carrier Aggregation
- Uplink Carrier Aggregation
- Downlink MIMO (>R8)
- Uplink MIMO
- Heterogeneous Networks
- Relays
- Self Organising Networks (SON)
- UE Advanced Receivers
- Coordinated Multipoint Transmission and Reception



LTE-Advanced Synchronisation, path to 5G

- Requirements for LTE-Advanced are well understood and aren’t expected to change with further evolution
  - Frequency 15ppb with G.823 traffic mask
  - Phase +/- 1500nS
- New requirements from 5G will depend on new waveforms or other technologies introduced for the air interface.
  - UF-OFDM / F-OFDM SCMA
  - Multicarrier schemes
  - CoMP
  - Massive MIMO, Full Duplex...

THANK YOU