Telecommunications Issues

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Representative Telecommunications Fields

- Wireless communications
- Radio and television
- Satellite communications

Basic Properties of Digital Communication

- Modulation
  - Phase Shift Keying (PSK)
    - BPSK
    - QPSK
- Multiple Access
  - Frequency Division Multiple Access (FDMA)
  - Time Division Multiple Access (TDMA)
  - Code Division Multiple Access (CDMA)

Network Synchronization

- Network divided into small synchronization regions
- Within each region, Master-Slave hierarchy of stratum clocks
  - Stratum 1 highest level of performance
  - Stratum 4 lowest level of performance
- Primary Reference Source (stratum 1 clock)
  - Accuracy of 1 part in 10^{11}
  - Realization
    - Autonomous cesium clock
    - Disciplined nonautonomous clock (GPS or LORAN-C)

Multiple Access Methods Requiring Synchronization

- TDMA
  - Frame size
    - Europe (GSM) 4.6 ms
    - USA 40 ms
  - Carrier bit rate
    - Europe (GSM) 270.8 kbps
    - USA 48.6 kbps
- CDMA
  - All users share the same sub-band
  - Data modulated by a pseudorandom noise (PRN) code
  - 12.5 MHz allocated to each cellular service carrier
  - Ten 1.25 MHz sub-bands
  - For 9.6 kbps vocoder data, processing gain is 130

Radio and Television

- National Association of Broadcasters (Washington, DC)
- Frequency more important than epoch
  - Many stations have cesium or rubidium clocks
- Stations derive time reference from parent station or GPS
- BBC time “pips” derived from GPS

Satellite Communications

- Earth station facilities have GPS receivers to maintain synchronization at each end
- Spacecraft mission TT&C typically based on internal mission elapsed time with external reference to UTC via software

Operational Impact of Leap Seconds in UTC

- Many applications in telecommunications require stable frequency reference and do not depend on epoch – unaffected by leap seconds
- Some engineering systems require preparations and rehearsals to implement leap seconds smoothly
- Some engineering systems are unavailable temporarily while clocks are reset
  - Glonass loses navigation service

Frequency of Leap Seconds in UTC

- In current system there will always be a need for leap seconds
- Frequency of leap seconds will increase
  - Possibly two leap seconds per year
  - Occurence can be at end of any month
  - Negative leap seconds are theoretically possible (although not probable)

Alternative Time Scales

- GPS is a common source for time
  - Easily available
  - Continuous without steps
- Some engineering systems adopt independent, internal time scales for a particular objective
  - Spacecraft mission operations

Motivation for Leap Seconds

- When current form of UTC with leap seconds was introduced in 1972, UTC was the only available source of disseminated time that could meet the needs of both celestial navigators and precise time users
- Development of GPS, together with Glonass and Galileo, has greatly diminshed this motivation
- UTC with leap seconds suspended
  - All the advantages of TAI and GPS Time
  - Negligible impact on social conventions
    - Estimated drift from UT1 is about 2 minutes by end of century
    - Current difference between UTC and apparent solar time varies by up to 16 minutes over the year

Conclusions

- Practice of inserting leap seconds into UTC encourages use of alternative time scales that are uniform
- GPS Time has become a de facto standard for many users
- Advances in technology and interoperability among systems (e.g., GPS and Galileo) requires a widely available scale of uniform time
- UTC without leap seconds could meet this objective