Next Generation Network Synchronisation Solutions for Packet Networks

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***Abstract*—As traditional telecommunications networks converge with data networks to form one ubiquitous transport medium, traditional synchronisation methods will have to be replaced with a variety of techniques to transport time and timing over the new infrastructure. This paper looks at some of the proposed solutions and suggests a topology for "Next Generation Network Synchronisation" networks.**

I. Introduction

The basic mechanism for synchronising telecom networks, put in place during the mid 90s following the global adoption of SDH and SONET transport technology and GPS as a stable sync source is under threat from two completely different directions.

On the one hand the steady migration of core and metro network architecture to an asynchronous Ethernet based transport technology from the synchronous process of SDH and SONET is potentially compromising resilient sync routes through networks. Despite best practise being not to use an E1 transported through an SDH network as a source of sync, industry has consistently flouted this rule, one of the best examples of this is the wireless base station. The E1 concept as a sync source was conceived and adopted in 1989 – long before SDH. Whilst SDH delivered E1 sync was generally fit for purpose if there were no pointer adjustments, this process will finally meet its nemesis when access technology migrates to packet transport and E1s have to be circuit emulated from Ethernet.

The second challenge which relates to GPS is separate but exacerbated by the arrival of the first problem. Telecom networks globally, have been major adopters of GPS technology to drive primary rate (conforming to stability required by ITU G.811) synchronisation into the network at many locations. Best practise has been to utilise the GPS source first but by using adequate QoS monitoring, adopt resilient back-up routes to a geographically distant GPS or Caesium primary reference in the case of local GPS failure. This process is particularly suitable for sync "islands" and potentially would suggest a solution if traditional sync transport methods in SDH overhead are likely to disappear. The ubiquitous availability of GPS is now taken for granted with the removal of selective availability and new generation of multiple-correlator high sensitivity GPS chip-sets. However this availability is under threat, not from the emergence of other Global Navigation Satellite Systems (GNSS) e.g. the arrival of the European Galileo system, but from localised jamming – both deliberate and accidental. This jamming could be caused by the subsequent co-location of another much stronger radio source. However there is a more insidious threat; that of deliberate jamming by terrorist or for tax evasion purposes if for example GNSS systems are adopted for road user charging schemes. Already GNSS jamming technology is readily available and cheap circuits are published on the internet.

So the question is raised – should critical telecom timing infrastructure rely on solutions and technology which is about to be or can be so easily compromised? This paper will examine the different emerging technologies and solutions and establish some proposals for best practise in the telecom industry for core and access layer time and timing (synchronisation) solutions.

II. Different Technologies and Solutions

Let us first examine the various technologies and solutions which are currently available or which are emerging as the Standards evolve.

Off-air and GNSS primary reference solutions include the existing GPS, with Galileo and Compass becoming available in the future, GLONASS receiving new funding and new life is being breathed into the relatively Jurassic LF solutions namely Loran and MSF.

NGN network sync solutions include Synchronous Ethernet, being proposed in the new ITU Standard G.8261 and a two way time transfer protocol emerging from the industrial robotics world known as IEEE-1588. In addition, the NTP protocol is being upgraded and there are a number of non-standardised bespoke one way solutions emerging.

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III. GPS

GPS has now been in regular use in the telecoms industry since the mid 90s. Early 90s quality problems due to incomplete coverage and the program delays caused by the shuttle disaster were overcome and the removal of selective availability in may 2000 meant that good primary reference source performance (in terms of MTIE) has been readily available for more than 10 years. Holdover and filtering is enhanced by adopting quartz or rubidium technology as a flywheel oscillator and many telecom networks use GPS receivers in their 100s as a timing enhancement at isolated, island or gateway locations.

Current status as at December 2006 is that there are 29 satellites currently operating in orbit with 3 non-operational satellites; 24 are needed for a complete constellation. Satellites comprise 14 Block IIA built by Boeing and launched between 1989 and 1997, 12 Block IIR and 3 Block IIR-M built by Lockheed Martin and launched between 1997 to present day with the most recent at time of writing being launched in November 2006.

Future enhancements include Block III satellites which will start being launched in 2008 with a new L2 civil signal. The challenge and enhanced QoS features predicted for Galileo has made the GPS designers look hard at future needs and Block IIIF satellites scheduled for 2012/13 will also offer better power and quality monitoring and reporting.

Here is a current minor technical firmware warning issued in Sept 2006 from the US Department of the Air Force that some GPS receivers may not be able to cope with recognising more than 32 satellites. This would only be a problem if existing non-operational satellites are brought back into service and may only impact certain older firmware and receivers. Some manufacturers, Symmetricom for example, have confirmed that this is not an issue.

GPS chip-set technology utilising new more sensitive low noise amplifiers at the receiver front end and multiple correlators to piece together fragments of reflected signal mean that PRC MTIE performance (without holdover) can be achieved for less than $100. This is a significant advance and will herald the widespread adoption of low cost GPS at the edge of networks to stabilise and provide inter base station time slot alignment for TETRA, WiMax and other TDD based radio technologies.

IV. GALILEO

Galileo was originally conceived by the European Community and European Space Agency as a civilian system under European control and aimed at critical commercial, safety of life and public regulated services.

Built by Surrey University, the first satellite GIOVE-A, was launched in January 2006. Another test satellite and 4 operational satellites are scheduled for launch through to 2009 with the full constellation of 30 satellites in orbit by 2012. All operational satellites will be built by EADS-Astrium.

Galileo frequencies share spectrum with GPS and GLONASS. The more accurate Galileo services will be chargeable, although charge models have not yet been defined.

Dual Galileo/GPS chip-sets and receivers are beginning to emerge, particularly aimed at the location and navigation markets. Some R&D work is taking place funded by the Galileo Joint Undertaking (GJU) to evolve a timing receiver design, but this is not due to complete for another 2 years. Private venture funded developments may be under way for timing receiver applications, but until a significant constellation is available and long term QoS is understood , it is unlikely to be adopted for critical network infrastructure.

V. GLONASS

GLONASS has suffered from a lack of investment in recent years. However a recent decision by the Russian Government to increase investment and presented by the Russian Federal Space Agency implies that the service will be developed in the coming years.

No telecom standard GLONASS receivers have been developed outside of Russia and it is unlikely that critical infrastructure would ever leverage GLONASS as a primary source of stability or time.

VI. MSF

MSF is a UK based LF broadcast at 60 KHz. It has been transmitted as a frequency reference monitored by NPL from Rugby radio station since the 1950s. This year a 10 year management contract was let to VT Communications which will build an entirely new system at Anthorn in Cumbria and will start transmitting in April 2007.

The rejuvenated system will provide stability traceable to UTC.

Traditionally MSF has never been adopted for critical network timing infrastructure since available receivers did not meet G.811 MTIE performance, and in addition, Rugby has been traditionally taken off the air for maintenance in August for 2/3 weeks.

Since MSF has only been kept alive by the UK Govt for one or two major users - one being Railtrack, it is unlikely to find major new adopters, particularly in the telecom environment.

VII. ELORAN

Loran-C was originally developed to provide a radio navigation service for U.S. coastal waters in the 1950's, subsequently extended to the whole of the US mainland. During the 1990s its strategic dependency was somewhat eclipsed by the emergence of GPS. Loran signals are centred at 100 KHz and stabilised by UTC traceable Caesium primary frequency standards.

Loran signals are very high-powered, so they penetrate cities, buildings and densely foliaged areas where other off-air (particularly GNSS) signals are often blocked. From a practical perspective, Loran is virtually unjammable because of its high power.

Enhanced Loran or eLoran is a Loran system that incorporates the latest receiver, antenna, and transmission system technology to enable Loran to serve as a back-up to, and complement global navigation satellite systems (GNSS) for navigation and timing. This new technology provides substantially enhanced performance beyond what was possible with Loran-C, eLoran's predecessor. All US Loran transmitters were upgraded to eLoran during 2004.

The UK has an experimental station at Rugby. The UK Government will support a UK based Loran transmitter with a 15 year upgrade and management contract to commence in 2007. This is because Loran has a considerably powerful and well funded user group in the UK coastal waters navigational requirements of Trinity House. France has committed to upgrade and support its stations until at least 2015 and Norway has committed to support at least past 2010. The German and Danish stations will be supported by UK and France respectively.

The Telecom industry through ATIS in the US is currently lobbying Congress for long term support of the Loran system as a technologically independent platform to GPS for use as a primary reference.

Trials conducted in the UK by Chronos with new technology Loran receivers are showing G.811 MTIE performance as good as current telecom compliant GPS receivers.

VIII. Synchronous Ethernet PHY

Synchronous Ethernet has recently been defined in the new ITU standard G.8261 and previously known as G.Pactiming. It is the concept of timing the bit rate of an Ethernet service so that the clock rate at the far end can be transferred through an Ethernet network to the local end. A reference timing signal traceable to a PRC is injected into the Ethernet switch using an external clock port. This signal is extracted and processed via a synchronisation interworking function before injecting timing onto the Ethernet bit stream.

This will necessitate significant changes to hardware infrastructure to implement and it may be some time before compliant hardware becomes readily available.

The fundamental concept can be likened to SDH STM Layer timing and should be considered as physical layer Ethernet timing. This technique will be ideal for larger carriers needing to transport timing throughout the network as they do today through the SDH or SONET overhead.

IX. IEEE-1588 V2

The IEEE-1588 V1 standard originated in the robotics industrial automation environment. It is a two way time transfer (TWTT) concept which transports the timing information within the packet stream. It is also known as a Peer to Peer (PTP) technique as timing can be transported using the two way correction process from point to point.

Originally IEEE-1588 had a ping rate of 1 second – this is being increased for version 2 due to be standardised in late 2007.

Like Synchronous Ethernet, IEEE-1588 will require a considerable overhaul of network elements, Theoretically it could work across a large network and some manufacturers have demonstrated quite exceptional results by allocating protected point to point Ethernet connections (Nortel PBT as described at ITSF).

The main issue is that if there is packet delay variation in excess of the timing transport stability required – for example from congestion or network rerouting activity, there is no chance for a TWTT solution, which essentially requires three traverses of the network to perform its function.

IEEE-1588 will probably find its role as a last mile timing transport solution and as such will compete with one way differential or adaptive timing solutions. It may achieve accuracies as good as a few microseconds in a relatively benign or well organised Ethernet environment without congestion.

X. NTP

Network Time Protocol (NTP) has been the standard way of synchronising clocks between computers to around 10 ms for many years. It is a TWTT process similar to IEEE-1588 and is being enhanced to deliver better performance. It will probably not be able to deliver a better performance than IEEE-1588.

XI. One Way Time Transfer

These methods are essentially performed using a reference to a common clock (differential) or adjusting and filtering the far end clock (adaptive). Essentially they are equivalent to the ATM SRTS and Adaptive clock techniques.

They will only transport a timing stability in a degraded manner in adaptive mode and will be dependent on the size of local oscillator and filtering phase locked loop.

XII. What should be used and Where?

GPS will remain the preferred off-air solution for global robust PRC timing.

However, whilst some carriers adopt a dual GPS approach to protect from receiver electronics failure or antenna failure from lighting strike, an equivalent or potentially more likely cause of failure is local interference or jamming. In this case Galileo (whilst well funded) will not be a solution as it is vulnerable to the same interference and jamming as GPS. GLONASS will suffer form the same interference and jamming phenomena and could be considered uncertain from a funding perspective. MSF is unlikely to be considered seriously by telecom operators. It is only a UK service and may not receive extended funding if major strategically important national users cease to require it. This leaves eLoran, now receiving major long term UK Government funding and international support as a strategically independent alternative to GPS.

Loran should be considered as an augmentation or authentication source for GPS.

Of the terrestrial techniques – Synchronous Ethernet will become the robust trans-network solution for major national carriers seeking an alternative to SDH or SONET timing transport processes. IEEE-1588 V2 may well find an application at the edge of the network as the preferred solution, it will probably struggle to deliver repeatable performance across a network due to the unpredictability of bandwidth availability and re-routing activity. NTP will be unlikely to develop beyond computer time synchronisation applications and bespoke one way timing solutions may well meet with objections from network operators keen to adopt a standardised approach.

XIII. FUTURE PROOF SYNCHRONISATION EQUIPMENT

With so many changes looming as networks evolve it will be vital for SSU/BITS platforms to be able to adapt to the various alternative NGN time and timing processes. Since some of the Standards will not be finalised for another 12 months a flexible architecture and future-proof roadmap will be essential to avoid large scale carriers ending up in expensive technological cul-de-sacs.