The Transport Infrastructure

"Carrier Scale Solutions - The Infrastructure Problem"
International Telecommunications Synchronisation Forum 2007
Mike Gilson

The Infrastructure Problem
“The Highways over which data flows”

Whats the problem?

- Train track too low?
- Road too high?
- Trucks / payload too big?
- Sat Nav not positioning you in the right place?
- Mapping wrong?
- Traffic routing wrong?
- Other?

Answers from the audience?

Inappropriate infrastructure for the operation being carried out!

GNSS is always right!

Maybe not?

Carrier Scale Solutions

- Delivering the right customer experience
  - Delivering the required services
  - Diverse & many applications over wide geographic areas
- Developing carrier scale solutions is about solving the infrastructure problem!
  - Correct models & methodology
    - Architecturally correct
  - Correct technology in the right place
    - Delivering the required performance over the technology
  - Correct commercial models
    - CAPEX / OPEX

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Agenda

- The scale of the problem
  - From the requirement through to applications at the heart of the customer experience
- Why do we need it?
  - The reference platform, resource convergence
- Balancing the requirements
  - Source, distribution, sink, the layer issue
- Some modelling approaches
  - Budgeting, Technology mapping, formal modelling
- Evaluation of the Approach
  - Iterative approach

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Requirement

- The requirement is an E2E issue.

- Stability and traceability
- …..is a key requirement in determining…
  - where,
  - how,
  - when,
- …information is transported from location to location (i.e. point to point)

- Positioning information…
  - in space,
  - and time,
- …is critical in determining the efficiency and effectiveness of resources

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Applications

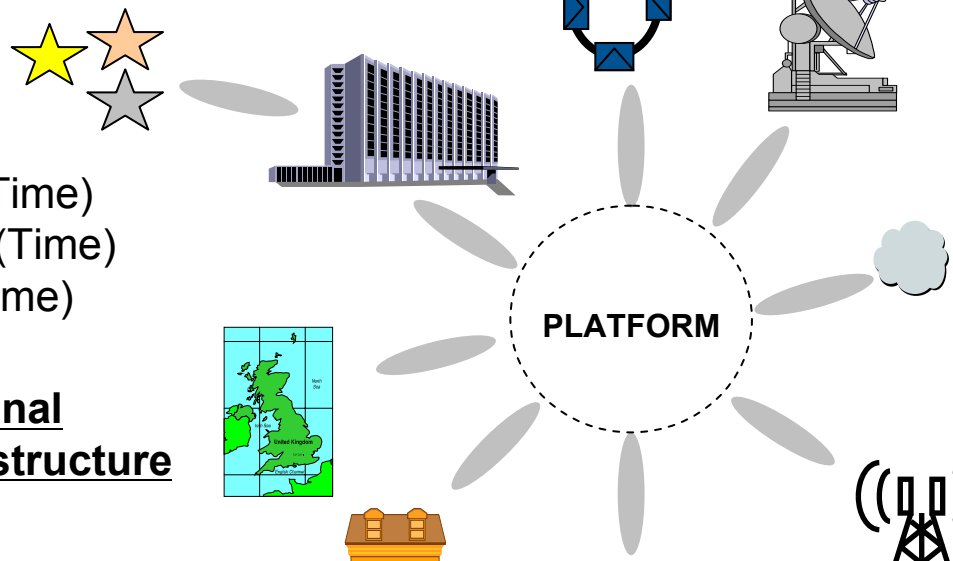
Sensors
-GeoLocation (Freq/Time)
-Smartdust (Freq/Time)

TDM Switching
-TDM/SDH (Freq)

Leased Line
-TDM/SDH (Freq)
-Cable / Sat modems (freq)

Business
-Legacy (Freq)
-IT Platforms (Time)
-Hosting Apps (Time)
-Digital Cert (Time)

Core Transport
-OLO (Freq)
-Legacy (Freq)
-IT Platforms (Time)
-Billing (Time)
-Alarm correlation (Time)
-Security (Time)
-SLA/Route/Efficiency (Time)



National Infrastructure

Residential
-Voice D/A (Freq)
-Future ResE Apps (Time)
-Femto cells (Freq / Time)
-Home Hub (Time)

Mobile
-2G & 3G (Freq & Time)
-LTE (Freq & Time)
-WiMAX (Freq & Time)

Broadcast / TV
-IPTV Streaming (Freq & Time)
-VoD (Time)
-Content / DRM (Time)

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The Customer Experience

- Synchronisation “The network heart beat”
  - Time & Timing

- Is at the heart of everything we do
- …It maybe hidden deep in the network
- …It maybe very close to the customer

- Either way when it goes wrong the customer experience
- …is very poor or
- …non existent!

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Synchronisation - Why do we need it?

- "The world is all packets – Sync not required!"
- Life is not simple
  - Migration of 20C to 21C
  - Some applications require synchronisation
- What do we mean by synchronisation
  - Commonly held to be frequency (timing)
  - In 21st century networks includes time
- New applications
  - Requirement for Time & Timing
- Embed the building blocks -> enable the future

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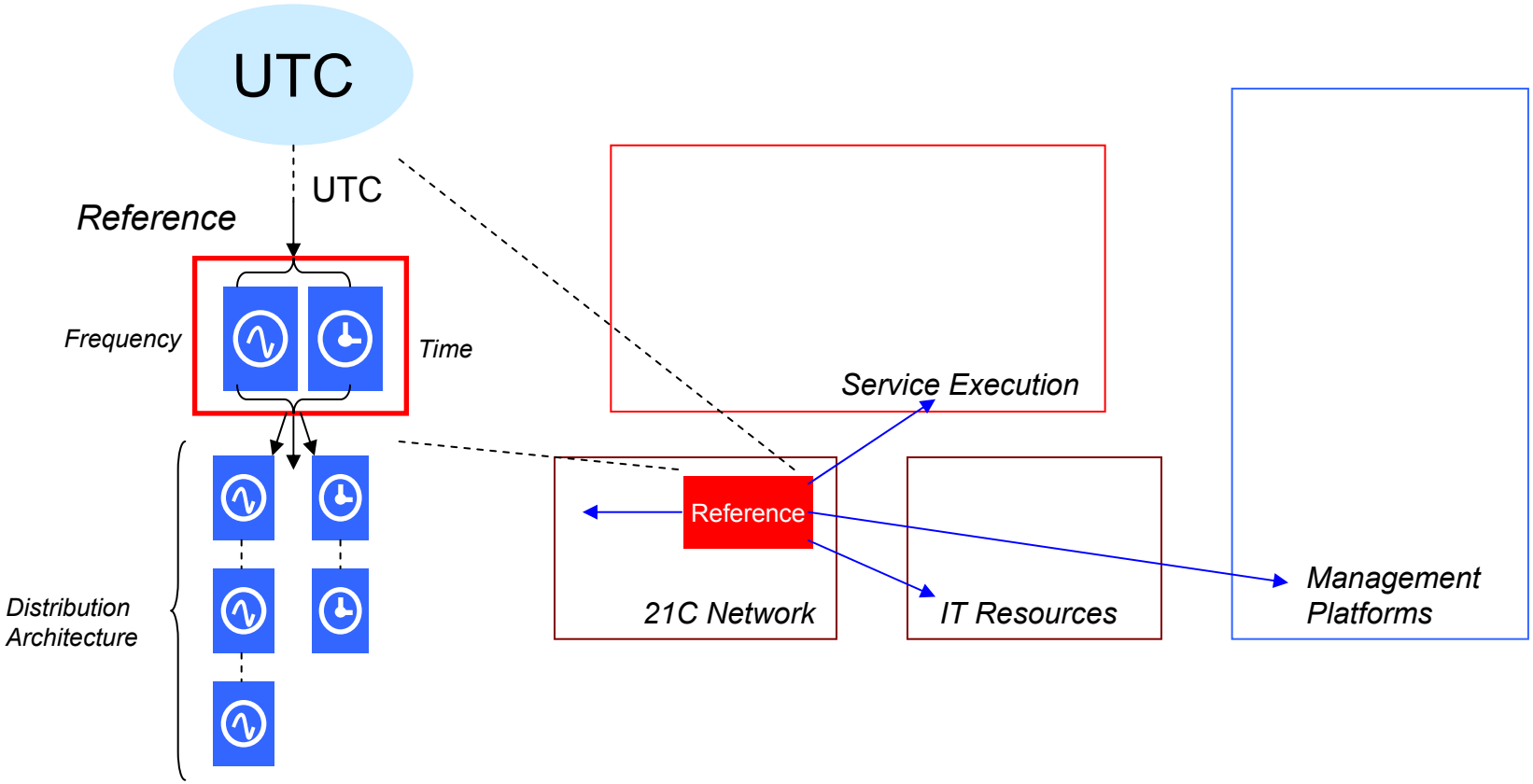
Reference Platform



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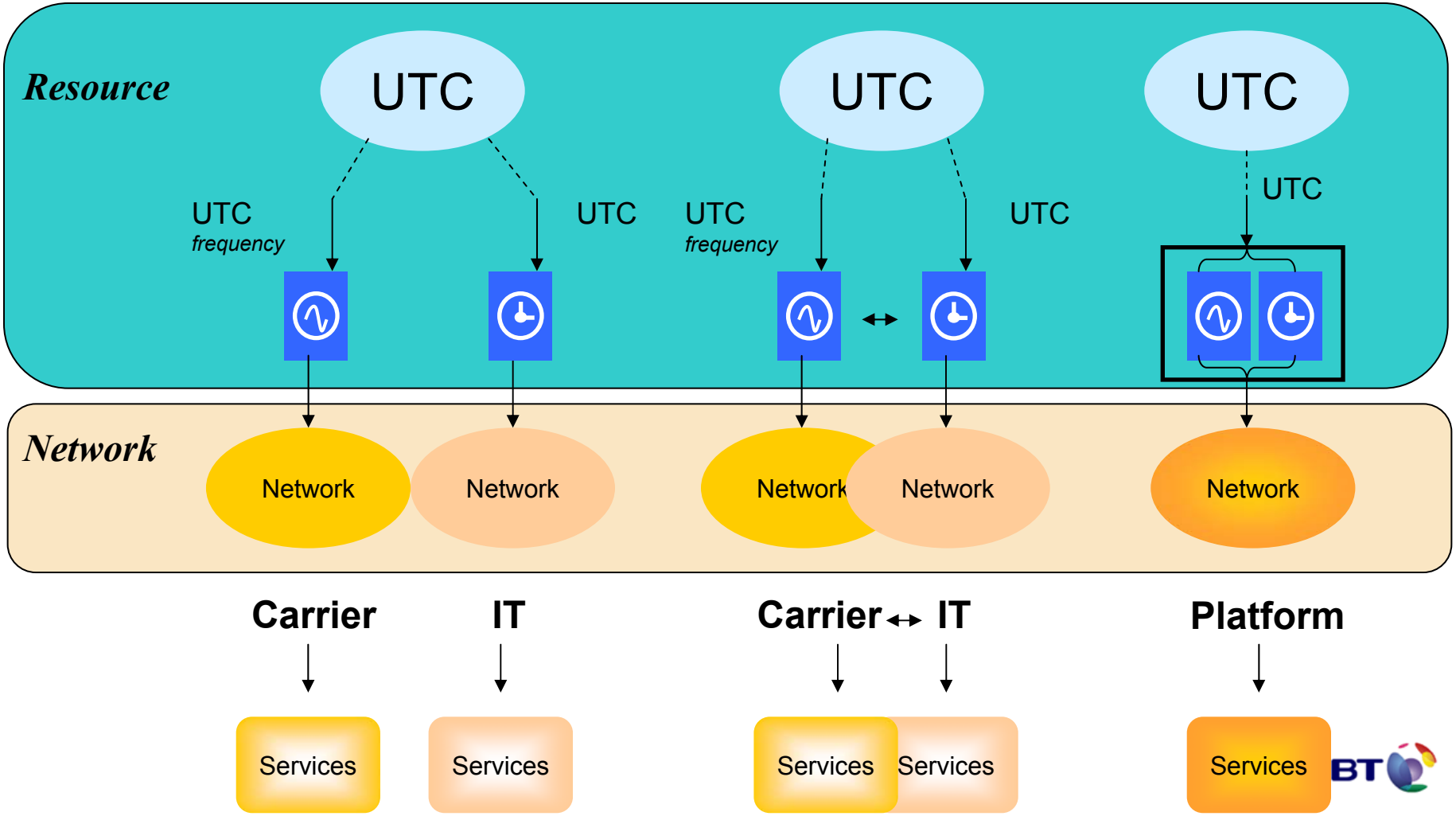
Network & Resource Convergence



Frequency & Time Relationship

- Frequency & time are related – a resource!
  - Carrier - traditionally required frequency
  - IT / computer networks – time

} converging

- Synchronous Ethernet – Layer 1
  - Can provide the frequency base in carrier scale networks
- IEEE1588V2 – Layer 2
  - Frequency & Time
  - Good frequency at the end points - Time lock quicker
  - Frequency base in native networks - limited
- Synchronous Ethernet & IEEE1588V2
  - complementary…in resolving frequency and time solution
- Network Timing Protocol (NTP) – V4 & V5
  - Ubiquitous layer 3 solution for Time based clients e.g. software only

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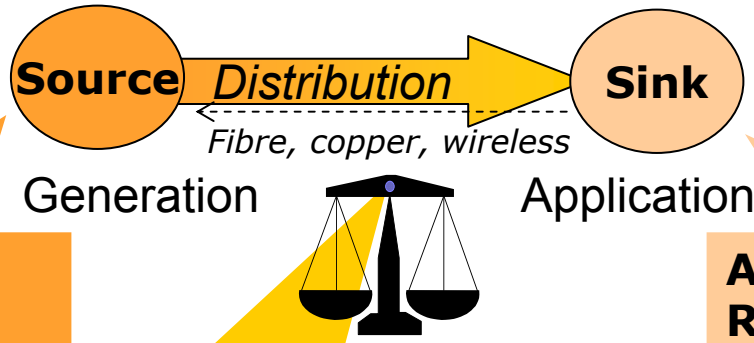
Balancing Requirements

Timing required at the Edge, Application or within the Network?
Choices based on various factors……
- Reference generation, distribution technology & balance of implementation issues.
These need to include, CAPEX, OPEX and a trade between Performance Vs Risk.



References -
Source of freq & time
-Caesium
-GNSS (i.e. GPS, Galileo, GLONASS etc)
-Radio based (i.e. stds institutes, NPL, NIST, Nav signals e.g. LORAN)

Architectures
-Core/Edge/Enterprise
Technology
-Ethernet (Sync or Native)
-xDSL
-xPON
-Packet Based
-TDM
-Boundary Clocks

Application Requirements
-Wireless (2G, 3G, LTE)
-Fixed
-Existing TDM
-Voice end points
-Boundary Clocks
-AVB masters

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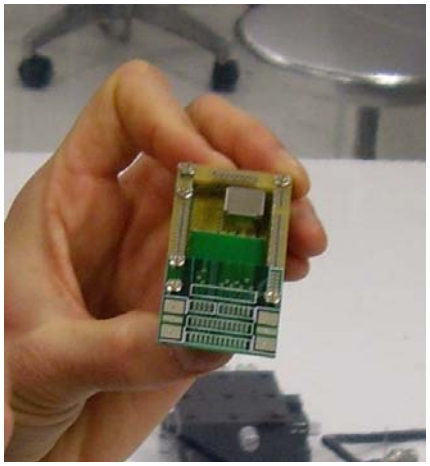
Sources - Based on Atomic Scale

NIST-7 Caesium Beam Tube Circa ~1990



NIST Chip Scale Caesium 2007

Big tube to chip scale

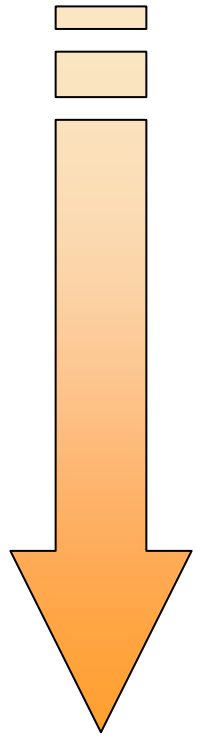
Distribution Solutions

- Layer 3 - Packet Based
  - Circuit Emulation TDM variants
  - Network Timing Protocol (NTP) Variants
    - Standard RFC / Modified H/W
- Layer 2/3
  - Precise Time Protocol, IEEE1588V2
- Layer 1 - Bit Based
  - TDM such as SDH
  - Synchronous Ethernet

Working down the stack

Clock recovery from packets

Clock recovery from constant Rate bit stream



Closer to the duct

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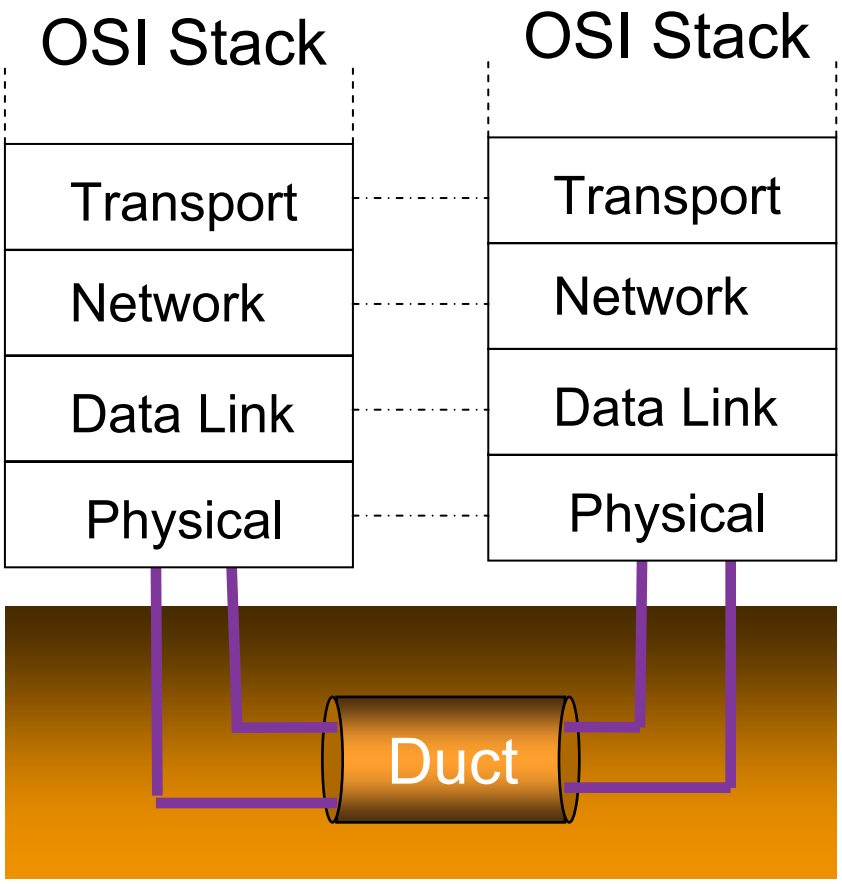
The Layer Problem

- "Science of the sensible"
  - Clock signals and oscillators are fundamentally analogue
  - Why translate from a stream with a given frequency to packets?
    - Unless you have to…
- Building up from the duct
  - Duct & fibre is a "given" & its stable
  - Physical Layer – next stable point
  - Adapting the frequency to a packet stream
- Performance inheritance



Performance Inheritance

- Clock recovery from packet based techniques has some fundamental problems
  - A range of techniques are available – not all have been fully characterised in standards
  - Packet jitter or more correctly Packet Delay Variation PDV will have an impact on clock recovery
  - Translation through the layers creates a performance inheritance problem
  - Optimisation of “Layer n” solution with PDV and differences in clock recovery algorithm will be problematic in creating a stable deterministic frequency at load points / operating scenarios

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ITU-T G.8261 Timing Techniques

- Network Synchronous
  - -PSN Physical layer distribution
  - -PSN/TDM only

Synchronous

- Timing within TDM end Systems & Networks
- Adaptive
  - -Based on pkt rate / buffer fill

Adaptive (for CE)

- Differential
  - -Based on timing messages
  - -Requires stable reference

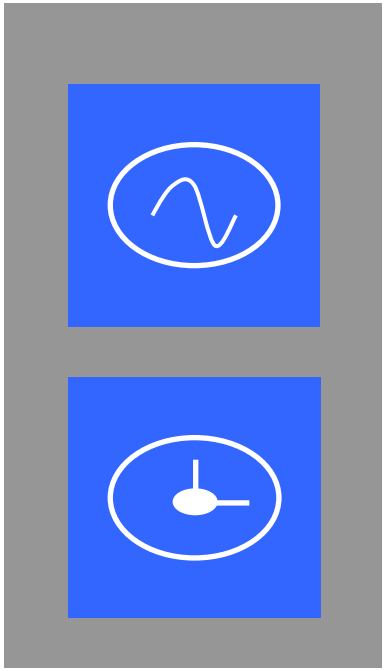
Differential (for CE)

- Time stamping techniques
  - –- One way or two way

Time Based

Timing Techniques

Frequency Based



Time Based

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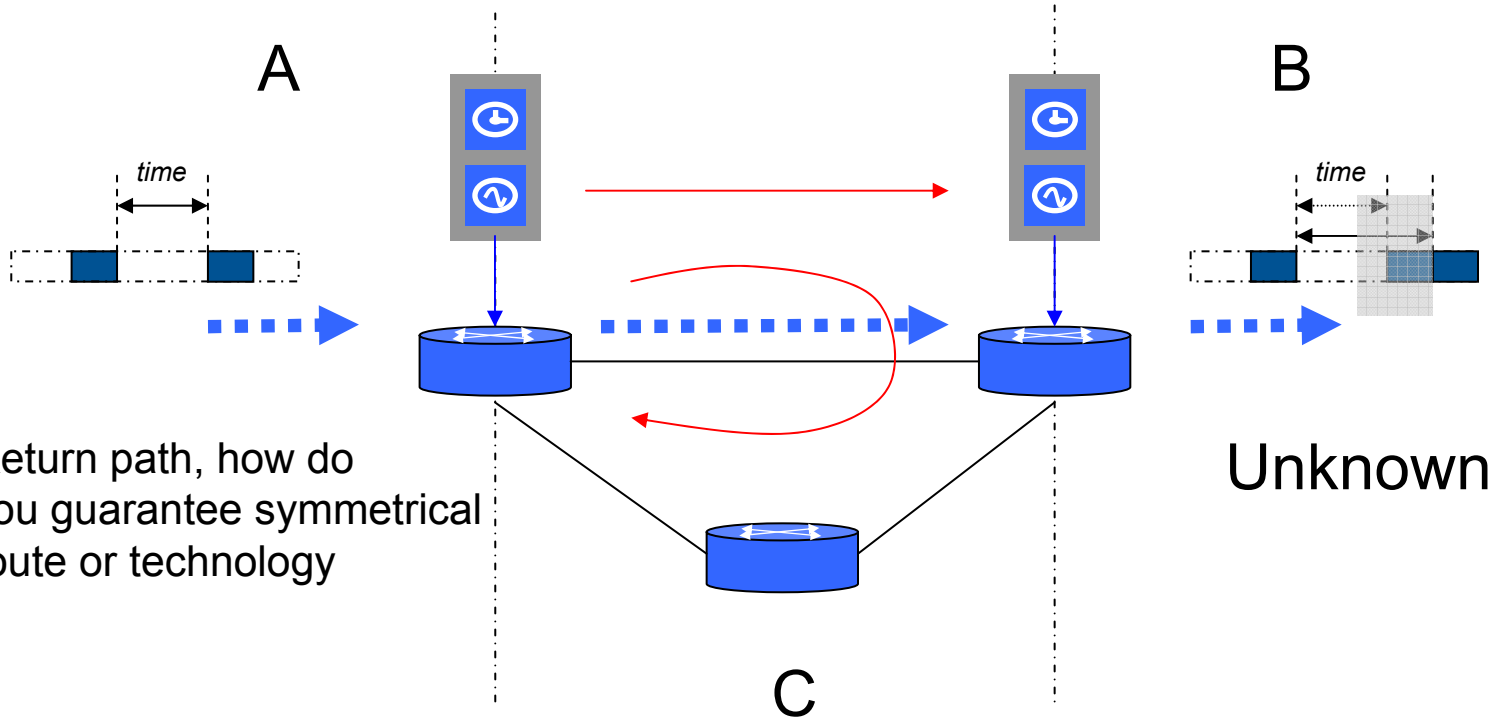
Flight Time

Absolute time provided
At end points or transported
Across network

Known time



Return path, how do you guarantee symmetrical route or technology

Unknown time!

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Audio & Video Perception Limits

- Maximum skews [1] that can be tolerated for various types of related streams before QoS would be perceived as poor
  - ±80 ms - Lip-synch; Video animation with accompanying audio
  - ±5 ms - Tightly coupled audio and images
  - ±10 μs - Tightly coupled audio (e.g., audio streams delivered to multiple speakers)
    - IPTV local advert inset / programme feed change (Probably < 10 μs)

Stretching the network technology to its limits!

[1] Ralf Steinmetz, *Human Perception of Jitter and Media Synchronization*, IEEE JSAC, Vol. 14, No. 1, January, 1996.

Modelling Approach

- Not all technologies can fit in all parts of the Core – Edge distribution space
  - Need to understand applicability
- Creation of appropriate models and reference circuits
  - High level scenarios
  - Budget Methodology
  - Formal Modelling
- Framework to determine the technology limits
- Understand how we can build large scale distributed networks
  - Optimise performance whilst removing complexity and thus cost

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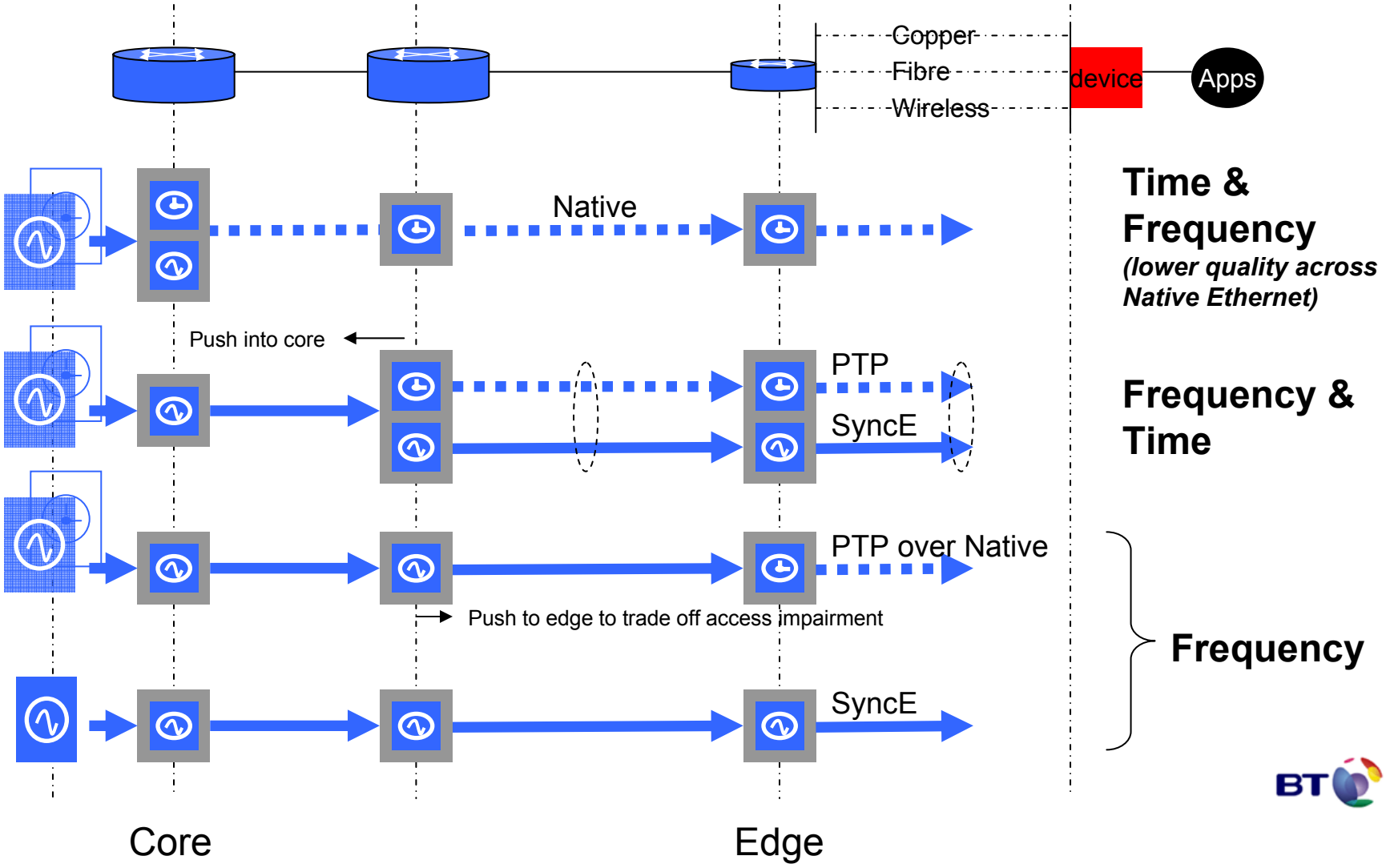
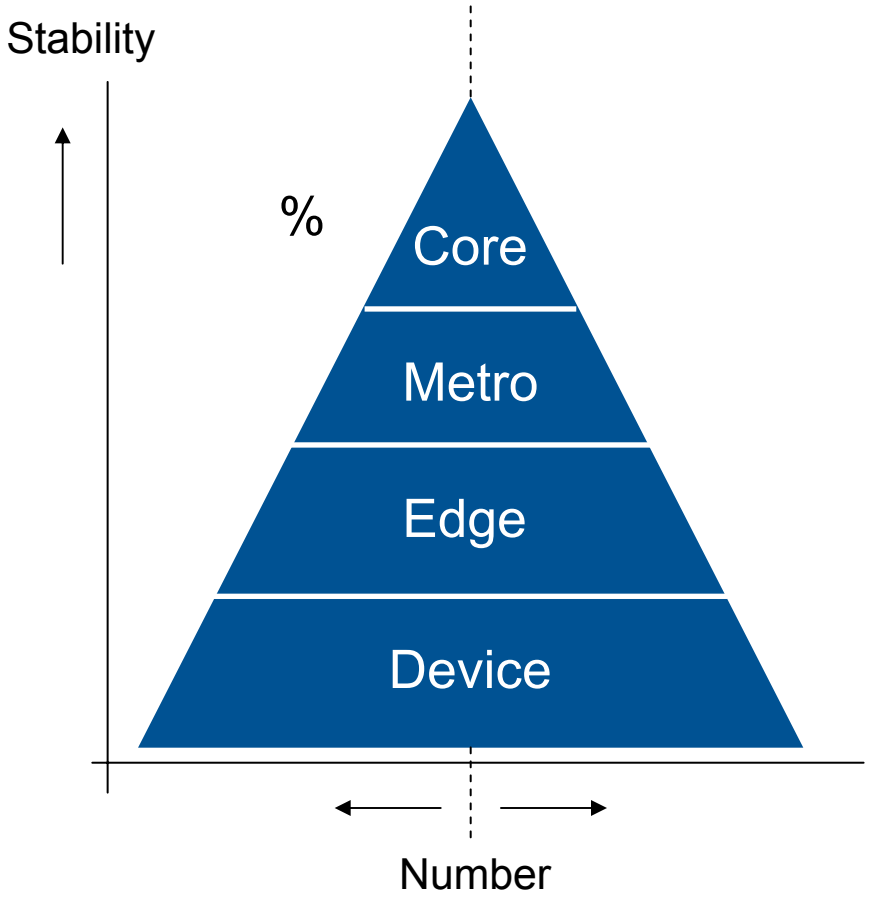
Reference Circuits
High Level Scenarios Combining Physical & Packet Based Solutions



Budget Methodology

Domain Budget Allocation [1]

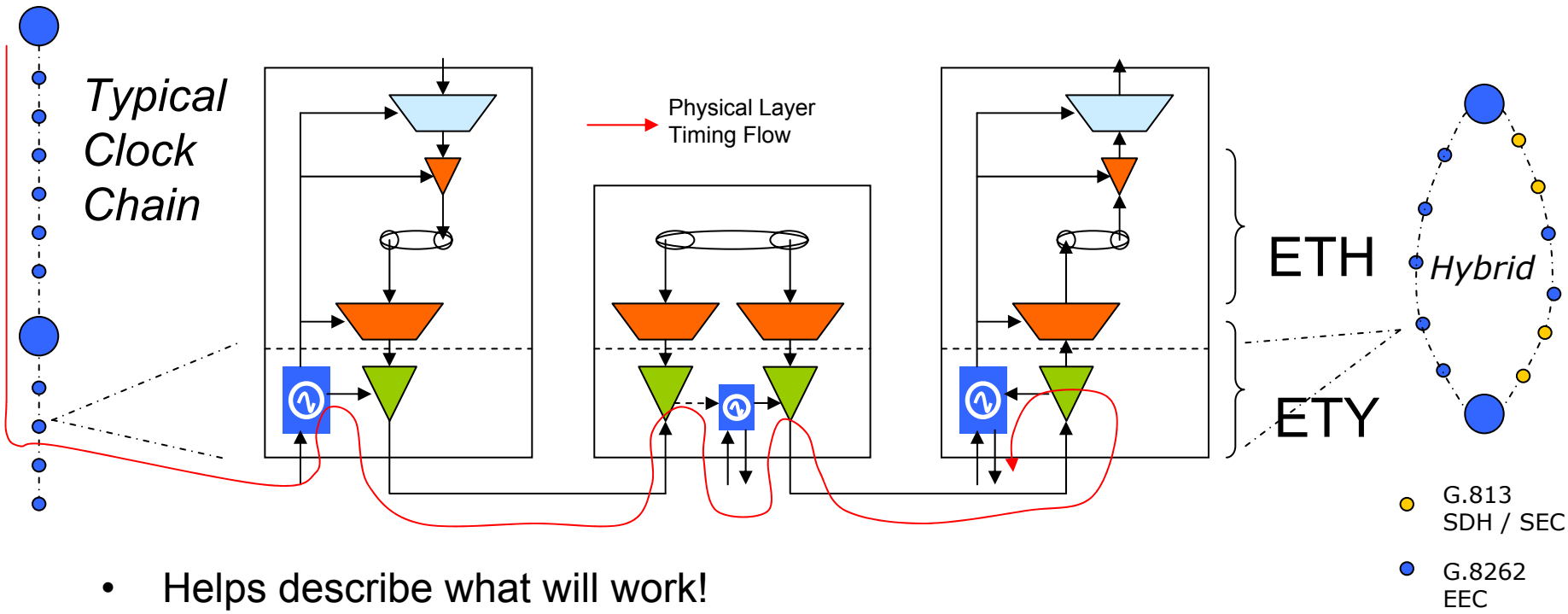


Technology Partitioning [2]

	Core	Metro	Access	Edge
Layer 3			Technology E	
Layer 2		Technology C	Technology D	
Layer 1		Technology B Technology A		

[1] Based on George Zampetti, *Framework for Packet Timing Network Modelling*, Symmetricom, ITU Contribution Sep 2007
[2] Mike Gilson, *Technology Partitioning*, BT ITU Contributions under development, Oct / Nov 2007

Formal Modelling



- Helps describe what will work!
  - –Currently being developed in ITU-T by extending formal modelling language into synchronisation space
- Synchronous Ethernet example
  - –Inter-connect / work with existing Synch architectures
    - SDH / Carrier Scale Ethernet, Chain limits are the same
  - –Easier migration path
    - Possible Hybrid working – Combined SDH / Ethernet Equipment

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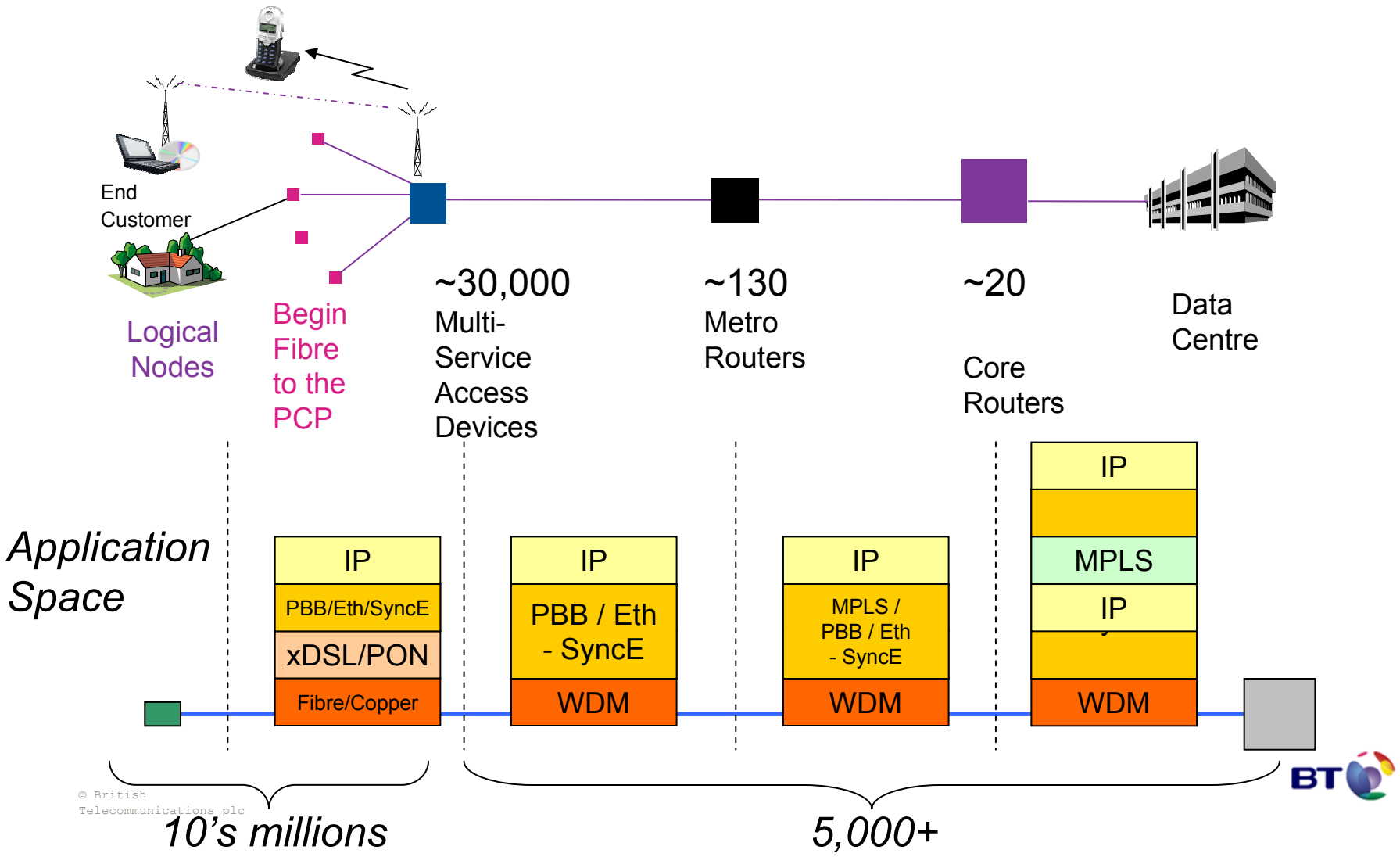
Remove Layers & Complexity



How do you evaluate your modelling approach?

- What's the timing performance?
  - Use the physical layer (layer 1) reasonably well understood
  - Existing metrics for evaluation of Timing – MTIE / TDEV etc
  - What about other approaches e.g. CE
    - Metrics for evaluation of the Core transfer performance?

- Theoretical performance
  - Paper based simulation
- Obtain end equipment
  - Simulate the network
- Evaluated E2E with an actual network
  - Creation of network load etc
- Obtain real network profile
  - Play back onto end devices
- All of the above?

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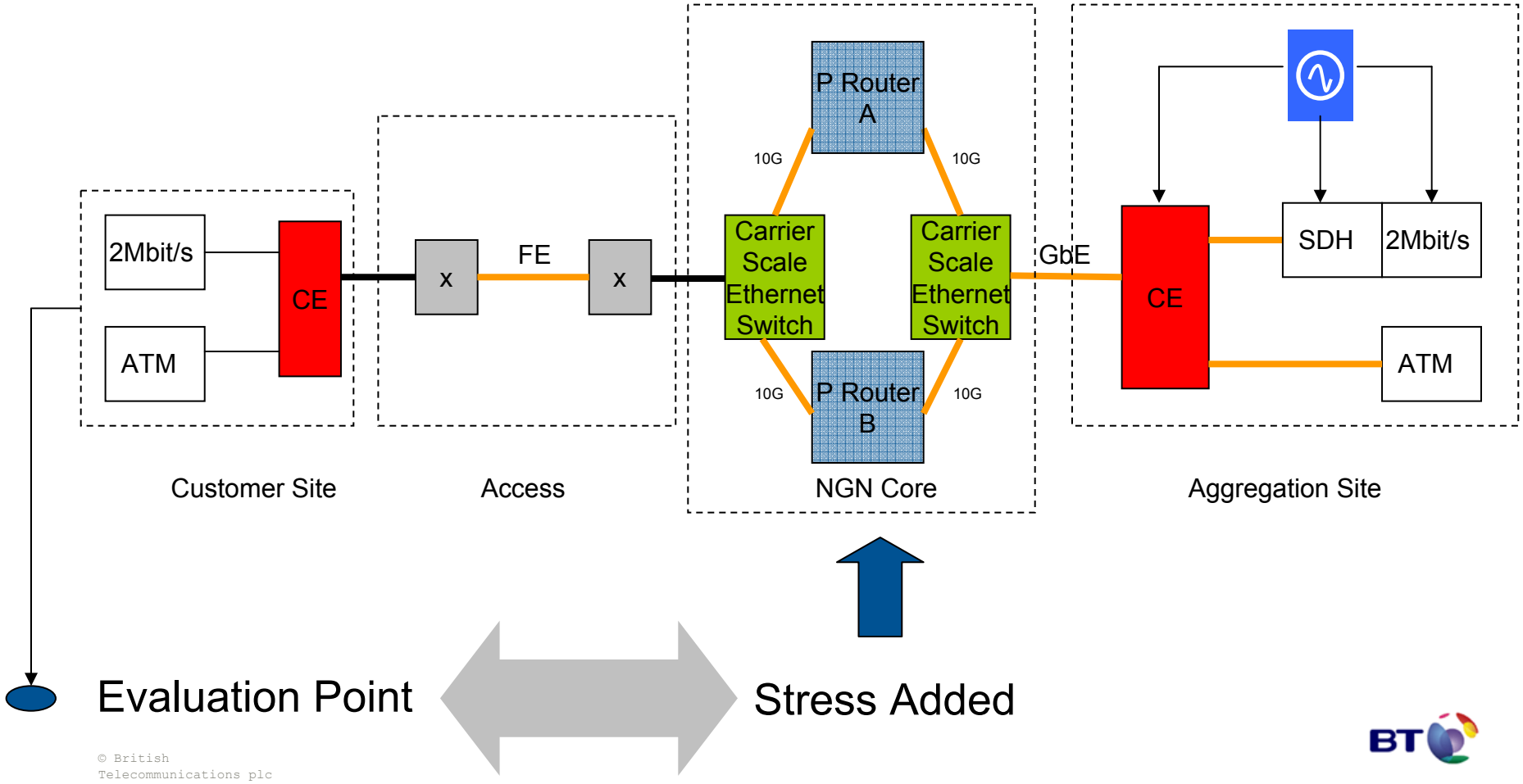
E2E Evaluation - CE Adaptive



Evaluation Concerns

- Creating complex network situations
  - Representative impairment & stress
  - Varying load - Time, Size, Rate of change etc
- Discrete test are not ideal as they do not mimic complex network situations i.e. varying load in real networks
  - However, they give a good feel!
- Concerns
  - Creating representative stress for initial & future implementations
- Cost & complexity of the test bed
  - CAPEX, running costs
  - Possibility of human error

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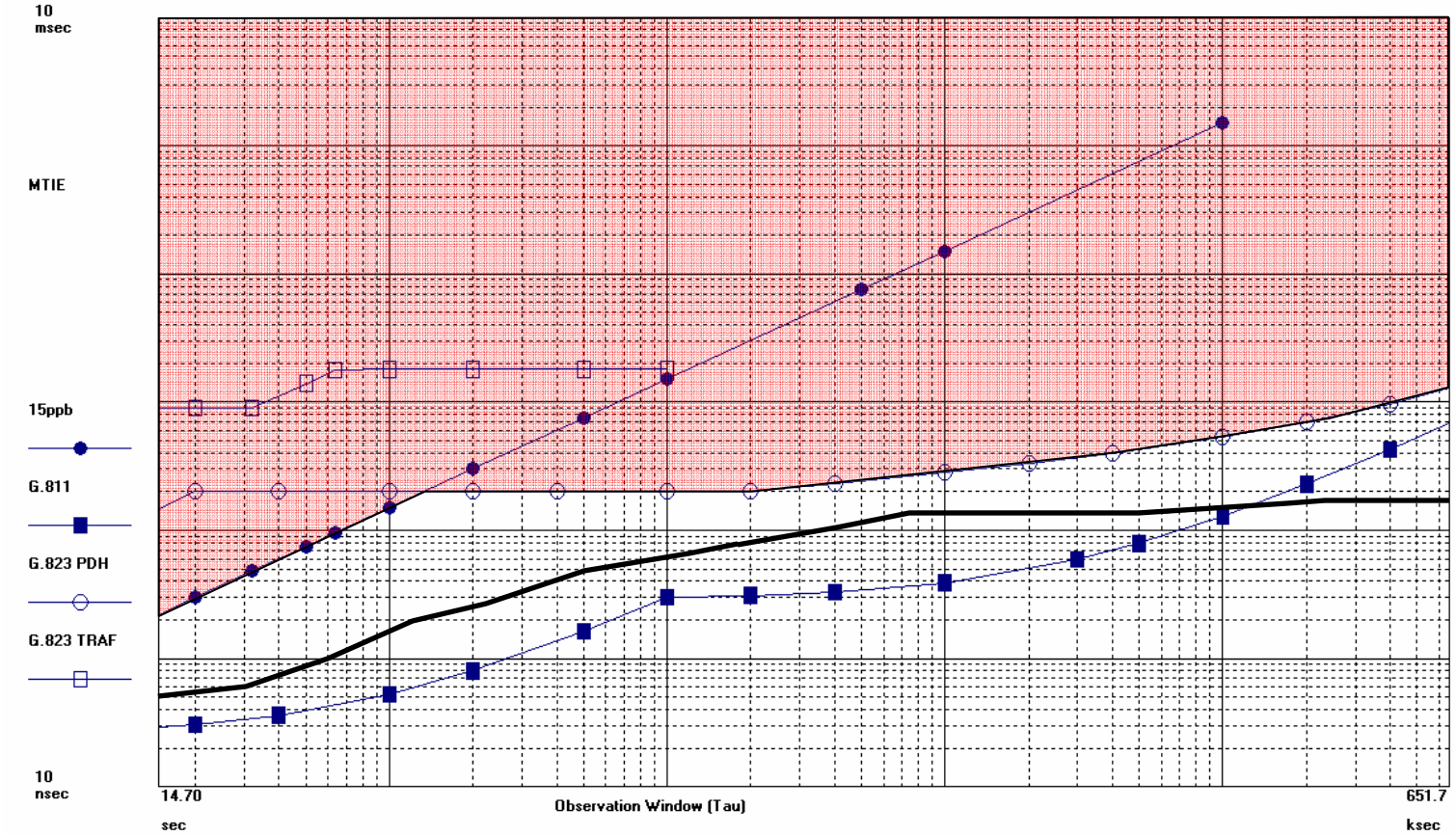
CE Adaptive - E2E Evaluation
Recovered TDM Synchronisation Performance

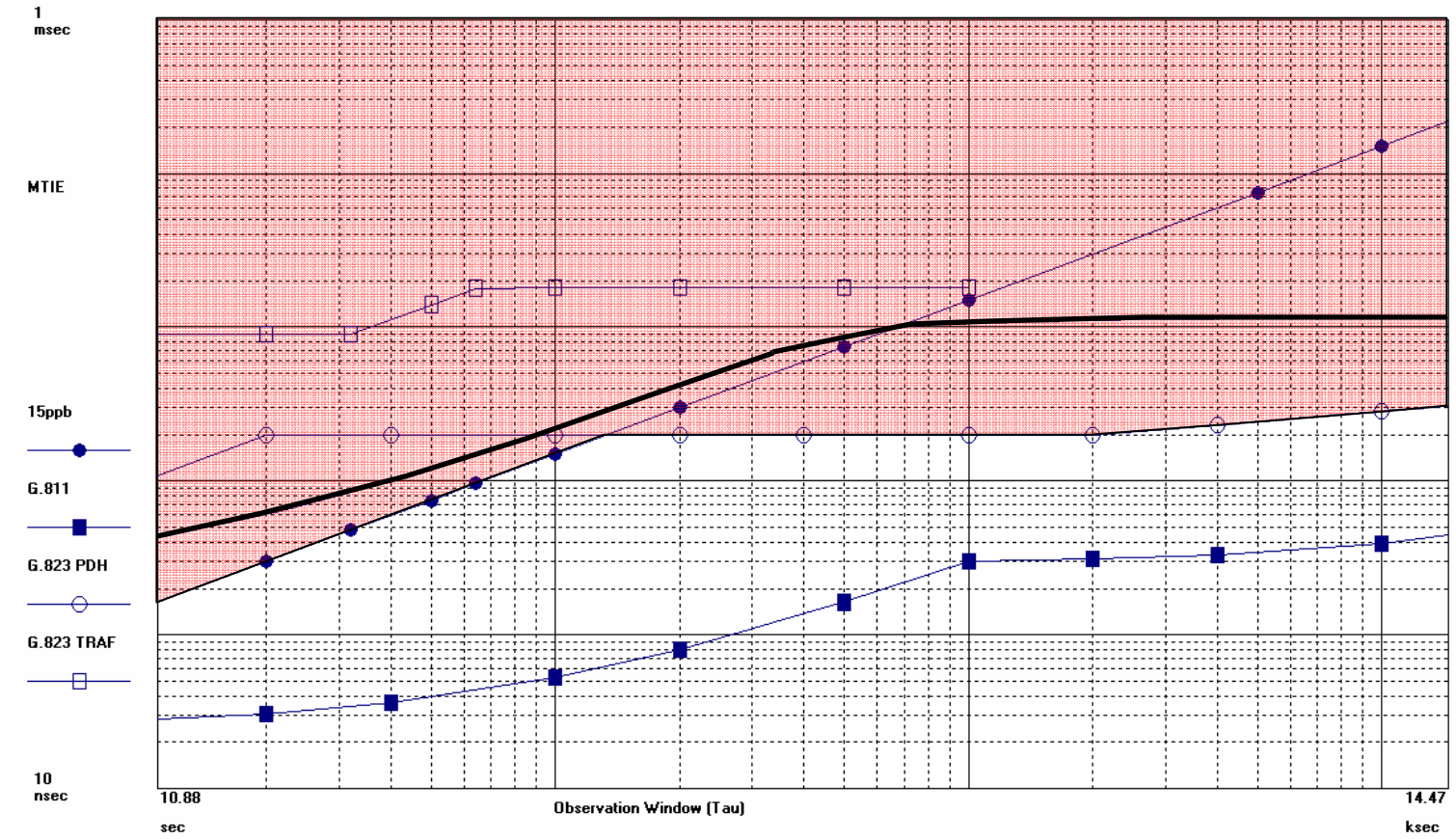
Range of stress tests over 7 ½ days
Recovered from transmit direction



CE Adaptive - E2E Evaluation
Impact of Significant Stress

Symmetricom TimeMonitor Analyzer (file=upload - 20070927 110000 to 20070927 150000.xls)
MTIE; Fo=2.048 MHz; Fs=91.91 mHz; 27-Sep-2007 11:00:01
Multichannel Tester Data; Channel 2; Samples: 1329
TDM emulation testing. Latency results

Result on Tx direction caused by <u>significant</u> stress



Iterative Approach

- Theory - Model - Evaluate
- Understanding of theoretical operation and impact on performance tells you which techniques work
  - For example, adaptive techniques will work
    - but will also suffer from stress
    - How much stress can be accepted?
      - Combination of many factors
      - Simulation may provide some answers
      - E2E testing actually uses the real environment, but does have some weakness
- Appropriate modelling and evaluation (standalone and E2E) can mitigate
- Allows us to build the correct infrastructure

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Model Correctly & Consider The Infrastructure

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