Selected auditing problems of rail telecommunication network model

Cliff Arnold
ADII
CQU
Rockhampton, Queensland, Australia
cliff.arnold17@gmail.com

Jacek Mocki
PhD, MSc, CPEng, MIRSE
MOTZKY Pty Ltd
PO Box 6401, Yatala, Queensland, Australia
business@motzky.com

I. INTRODUCTION

In the digital connectivity, big data and cybersecurity world, rail telecommunication becomes more important than ever before. For example, in the ’80s, the European Rail Operators ran a lot of fibre optic networks but the transmitting/receiving devices had limited capacity. Nowadays, telecommunication networks are massive in terms of the functionality which they provide to Rail Operators. Safe, reliable and available rail systems and a variety of wayside information systems are an endemic part of train operations, to the extent that the ability to map and model where these vital services flow through a telecommunication network is essential to rail planning and management regimes.

Having said that, an instrument that can logically analyse service failures, consequential to the simulated multiple breakdowns of modelled infrastructure, would automatically realise the potential to improve, innovate and support rail telecommunication applications. Perhaps more importantly, the model intrinsically provides an enumerated account of spare capacity, which is beneficial to identifying payload bottlenecks or future opportunities for third party backhaul.

II. LITERATURE REVIEW

In our previous two articles – “Rail telecommunication network documentation and modelling” (published by Rail Engineer.uk in November 2017) and “Essential functions in rail telecommunication network modelling” (published by Rail Engineer.uk in December 2017), we have described references applicable to this article [1]-[23] that review basic literature relevant to modelling a rail telecommunication network including auditing the model. In this article, we only describe the additional literature; however, all literature is listed at the end of this article.

III. RELEVANT TELECOMMUNICATION HISTORY

The advent of digital bit stream technology over a fibre optic medium as opposed to an open wire pole route realised an added benefit. Failure of a copper wire medium (e.g. storm damage) renders the whole party line service unusable due to induced earthing noise, whereas failure of the fibre optic medium (e.g. earthworks) occurs with controllable consequences. The bit streams on unbroken fibre optic cable remain intact and noise free, therefore communications to stations each side of a broken fibre optic cable are still possible provided there is a contingency path that will bypass the broken section of fibre optic cable.

Rail Operators realised the potential in bolstering the reliability of communications to remote stations. Contingency paths would only be successful if they were not co-located in the same damaged cable, so in many cases Rail networks invested in the broad band Microwave Radio medium to transport the contingency paths of bit streams of critical services.

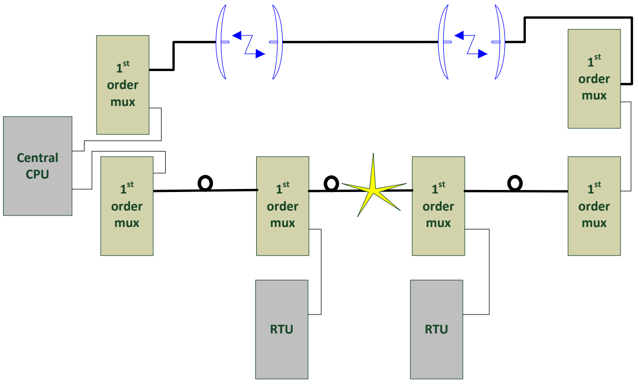


Fig. 1. Contingency path bit stream via Microwave when fibre optic cable is broken

The deployment of Microwave Radio systems provided yet another added benefit - the tower infrastructure was a means to establish in-cabin two way radio communications between Central Rail Operations staff and locomotive drivers.

The notion of high reliability communication Networks began to take shape as the functionality available with digital communication services was realised.

On the rail systems application side, the power supply to an electric locomotive is controlled by a Serial Control and Data Acquisition (SCADA) system. This system also needs rail telecommunication to reliably collect the input data and control the outputs.

Railways invested quite heavily in all manner of electronic technologies to monitor rail infrastructure (points operation, bridges, flood levels, train condition and many more). All those system are usually independent and require data transmission to their central computers that conduct data analytics, including data trending. The results of those analytics are transmitted to the relevant engineering/operation departments. Reliable and fast transmission is absolutely essential.

Rail telecommunication began deploying multiplexing equipment to form the backbone of their network, and the digital revolution had begun. Initially, Plesiochronous Digital Hierarchy (PDH) was deployed (a technology used in telecommunications networks to transport large quantities of data over digital transport equipment such as fibre optic and microwave radio systems). PDH is now successively being upgraded to Synchronous Digital Hierarchy (SDH). SDH is the most frequent transport technology used in long-haul networks. A multitude of those streams can be transported simultaneously through the same fibre over dense wavelength-division multiplexing (DWDM) technology.

In the deployment of the SDH network, many experienced the biggest hurdle of present telecommunication – the equipment is no longer endemically linear in design. There is a completely different approach needed to document the telecommunication network. Maintaining single line diagrams does not make any sense due to the dynamic character of the network. The introduction of network modelling, with an option to automatically generate linear diagrams to support maintenance or upgrade, works with the ability to quickly document the changes to the centralised documentation database.

IV. AUDITING OF NETWORK MODEL

Auditing is inherent to any data model in order to maintain confidence in the information it provides. The following examples describe several methods and outcomes that are incorporated in our data model.

Fig. 2 through to Fig. 5 explain how the model tests the integrity of an amalgamated data service, allocated to containers with the SDH Network.

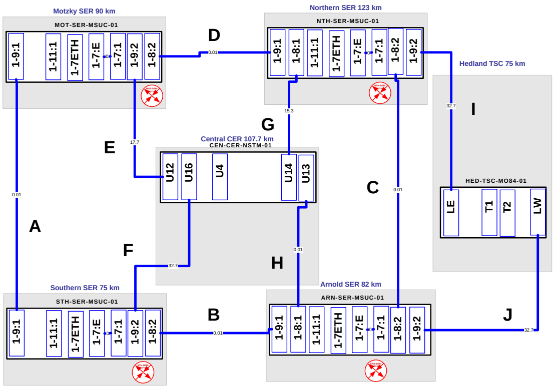


Fig. 2. Switch networks vs Routed network.

This image (Fig. 2) is considered by the authors to be the most minimalistic view required by a human being to comprehend how a service is applied to a complex SDH network. Routers (in red) are all interconnected via the SDH backbone payload. Fibre optic borne bit streams are marked A-B-C-D-E-F-G-H-I-J.

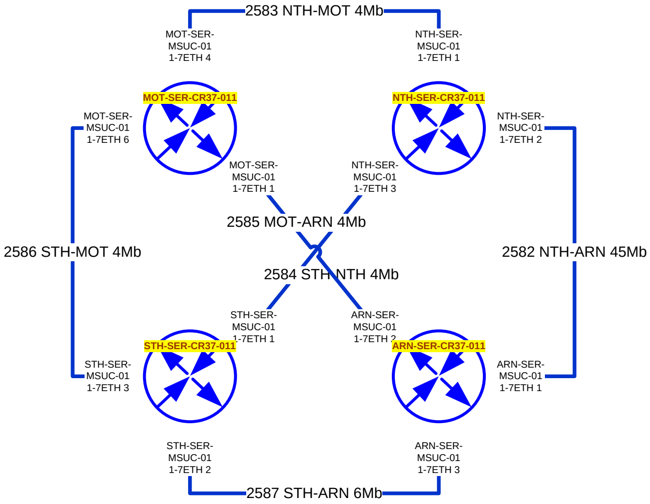


Fig. 3. Router connectivity from an IT perspective

In the routed network, the Transport domain topology is invisible; the routers and their subsequent interconnectivity appear as per Fig. 3. Looking at this diagram, it is easy to **assume** that the structure of data interconnectivity is robust by design and traffic can re-route around any break that may occur in the SDH transport network. The diagram you see here is automatically generated before any service analysis is performed due to a scheduled break in a SDH bit stream.

The entire overall routed service (Fig. 3) is an amalgamation of six subservices which form the individual connections between the four routers. The six sub services are denoted uniquely by the integers 2582, 2583, 2584, 2585, 2586 and 2587. The bit stream paths for each of the six sub services are not obvious in Fig. 3, however they are as follows:

- 2582: H-G
- 2583: G-E
- 2584: F-G
- 2585: C-G-E
- 2586: B-H-G-D
- 2587: F-G-C.

Note the G bit stream is common to all six service paths.

This commonality gives rise to a situation known as co-location, which is detrimental to the integrity of the overall amalgamated service.

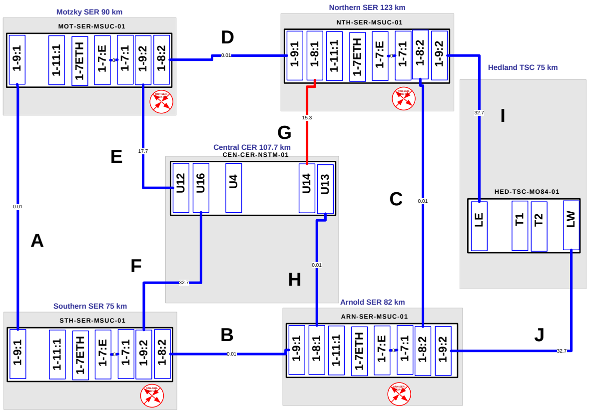


Fig. 4. Simulating a break to bit stream “G”

Now by simulating a “break” to bit stream “G” as demonstrated in diagram Fig. 4 (red highlight), the model is able to detect co-locations of the overall amalgamated service.

The subsequent automated drawing of the overall data service ref (Fig. 4) reveals in red any failures of service connectivity transiting the solitary break in bit stream “G”. In this situation the entire data service will fail completely due to a solitary break!

Notably, the model is able to detect co-locations in any service …

Fig. 5 determines the service status. The drawing is auto-generated after the simulated break to bit stream “G”.

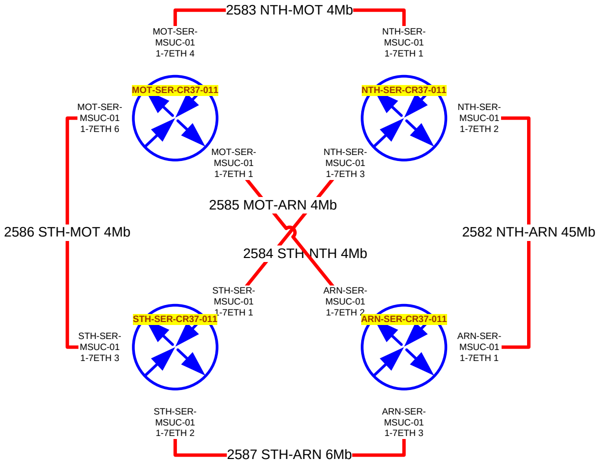


Fig. 5. Autogenerated drawing

It is revealed that the break to bit stream “G” interrupts all interconnections between all four routers. It is concluded the co-location of interconnected data links occurs in bit stream “G” and the fragility of the seemingly robust nature of the amalgamated router service is revealed (refer to Fig. 3 for a comparison).

Visual assessment of service integrity is rare in commercial grade solutions.

Before going into the details of the visual assessment, it is essential to introduce the terms “As Built” and “Is Built”:

- “As Built” refers to the configurational design at the point of commissioning acceptance
- “Is Built” refers to the configurational state of play at any chronological point after commissioning.

The model allows software auditing of configuration data by retrieving Nokia branching configurations from field devices. The model will reveal differences between modelled data and their real world counterpart in a visual fashion. An electronic soft auditing diagram is presented in Fig. 6.

A red colour highlight denotes the “Is Built” branch configuration is detected and is in conflict with the “As Built” data for this interception point of the diagram. A green colour highlight denotes the “As Built” branch is missing and is in conflict with the “As Built” data for this interception point of the diagram.

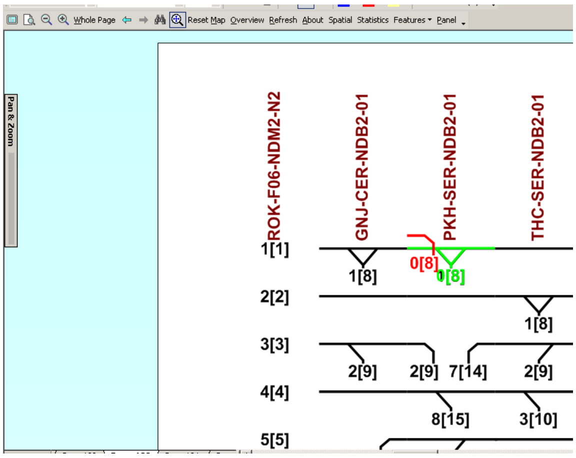


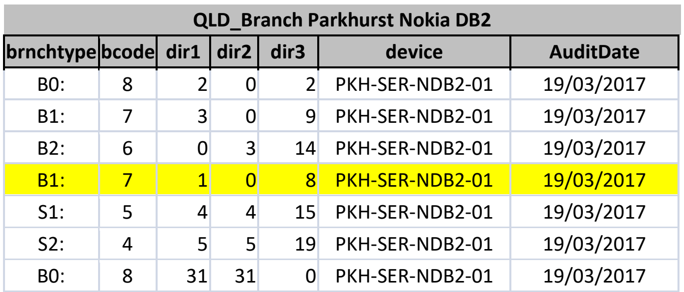
Fig. 6. Electronic soft auditing

In this instance, the PDH timeslot useage diagram was automatically produced; thereafter, auditing code was initiated to detect and illuminate the configurational differences between “As built” and “Is built”.

Corresponding with Fig. 6 is Fig. 7. The information in Fig. 7 was used to drive the automated drawing of Fig. 6 and generate the red/green conflicts seen on that diagram.

The tabular information in Fig. 7 is sourced from the actual Nokia DB2 machine at ‘Parkhurst’ (PKH-SER-NDB2-01), which shows a B1 (branch from direction 1 interface) on timeslot 1 toward timeslot 8 in direction 3 (highlighted in yellow on this table).

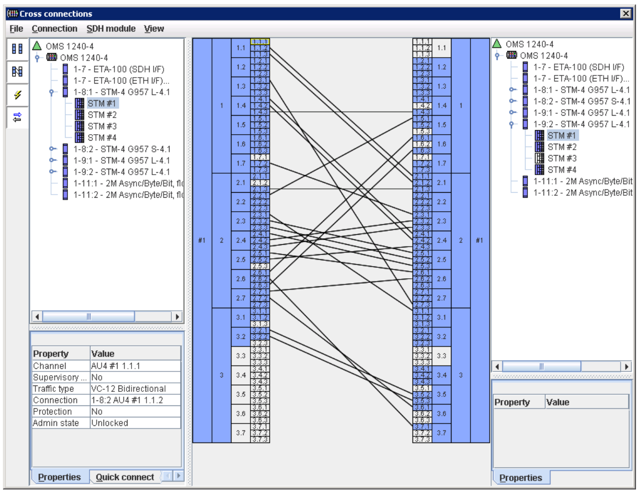
The “Is built” information (yellow highlight on Fig. 7, red highlight on Fig. 6) conflicts with the modelled “As built” information (green highlights on Fig. 6) at this interception point. The conflict is visually indicated in Fig. 6.



QLD_Branch Parkhurst Nokia DB2						
brnchtype	bcode	dir1	dir2	dir3	device	AuditDate
B0:	8	2	0	2	PKH-SER-NDB2-01	19/03/2017
B1:	7	3	0	9	PKH-SER-NDB2-01	19/03/2017
B2:	6	0	3	14	PKH-SER-NDB2-01	19/03/2017
B1:	7	1	0	8	PKH-SER-NDB2-01	19/03/2017
S1:	5	4	4	15	PKH-SER-NDB2-01	19/03/2017
S2:	4	5	5	19	PKH-SER-NDB2-01	19/03/2017
B0:	8	31	31	0	PKH-SER-NDB2-01	19/03/2017

Fig. 7. Portion of imported data. Note information (yellow row) is detected in (Fig. 6)

Auditing at 64 Kbit (voice channel) level of service delivery is rare in commercial products, due to the complex variations of brand hardware deployed in large Networks and the variations within the genres of brands.



Property	Value
Channel	AU4 #1 1.1.1
Supervisory ...	No
Traffic type	VC-12 Bidirectional
Connection	1-8:2 AU4 #1 1.1.2
Protection	No
Admin state	Unlocked

Property	Value

Fig. 8. Machine Cross Connections [25]

The model caters for visual auditing. The image in Fig. 8 is the user interface view of the SDH configuration of an actual Marconi node in a real world network. Note the SDH containers left hand side top to bottom 1:1:1:1 through to 1:3:7:3 on card 1-8:1. Right hand side 1:1:1:1 to 1:3:7:3 on card 1-9:2. The black lines connecting individual containers are refered to as cross connections.

The Marconi machine image in Fig. 8 is mimicked in the auto generated diagram Fig. 9; the SDH configuration is auto-generated from the Network Model. The concept of visually auditing data accuracy by virtue of an image comparison focuses on the ability of the human eye to discern differences in visual patterns as opposed to differences in alphanumeric texts.

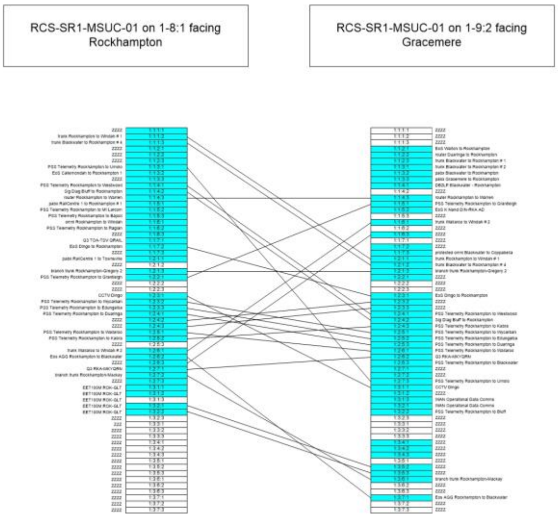


Fig. 9. Modelled Cross Connections

This image Fig. 9 is used to visually audit the cross connections in the same node and cards from Fig. 8.

The term “As Built” refers to the configurational design at the point of commissioning; the term “Is Built refers to the configurational state of play, chronologically after commissioning. Any disparity between the two images “As Built” in Fig. 9 versus “Is Built” in Fig. 8 can be readily identified using this visual auditing method.

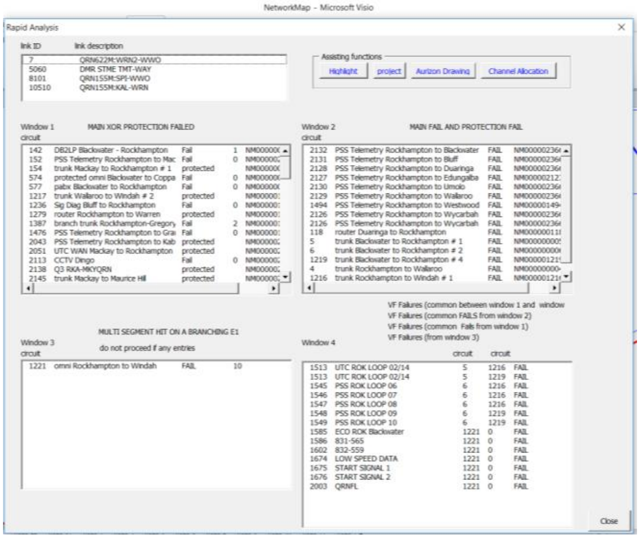
Moreover, the machine image of Fig. 8 can be imported into the Model’s graphic environment and overlaid with the image of Fig. 9. Any variation between the two images become visibly obvious.

The method is a visual comparison between modelled “As built” SDH connections and machine “Is Built” cross connections.

Note, the Marconi machine image of Fig. 8 does not cater for naming of the service allocated to individual containers, while the modelled image of Fig. 9 provides service names on the extreme left hand and right hand sides of the auto generated image.

The machine cross connects may be exported as a .CSV file or bland text, and imported into the model’s data domain for software auditing, similar to the method used for PDH soft auditing as described in Fig. 7.

However, the scripting methods and code descriptions required to do this are not submitted with this paper, albeit are available from the author on request.



NetworkMap - Microsoft Visio

Rapid Analysis

```
link ID     link description
7           QRN622M:WRN2-WWO
5060        DMR STME TMT-WAY
8101        QRN155M:SPI-WWO
10510       QRN155M:KAL-WRN
```

```
Window 1          MAIN XOR PROTECTION FAILED
circuit
142   DB2LP Blackwater - Rockhampton     Fail        1  NM00000
152   PSS Telemetry Rockhampton to Mac   Fail        0  NM00000
154   trunk Mackay to Rockhampton # 1    protected      NM00000
574   protected omni Blackwater to Coppa Fail        0  NM00000
577   pabx Blackwater to Rockhampton     Fail        0  NM00000
1217  trunk Walaroo to Windah # 2        protected      NM00000
1236  Sig Diag Bluff to Rockhampton      Fail        0  NM00000
1279  router Rockhampton to Warren       protected      NM00000
1387  branch trunk Rockhampton-Gregory   Fail        2  NM00000
1476  PSS Telemetry Rockhampton to Gra   Fail        0  NM00000
2043  PSS Telemetry Rockhampton to Kab   protected      NM00000
2051  UTC WAN Mackay to Rockhampton      protected      NM00000
2113  CCTV Dingo                         Fail        0  NM00000
2138  Q3 RKA-MKYQRN                      protected      NM00000
2145  trunk Mackay to Maurice Hill       protected      NM00000
```

```
Window 2                     MAIN FAIL AND PROTECTION FAIL
circuit
2132  PSS Telemetry Rockhampton to Blackwater  FAIL  NM00000236
2131  PSS Telemetry Rockhampton to Bluff       FAIL  NM00000236
2128  PSS Telemetry Rockhampton to Duaringa    FAIL  NM00000236
2127  PSS Telemetry Rockhampton to Edungalba   FAIL  NM00000212
2130  PSS Telemetry Rockhampton to Umolo       FAIL  NM00000236
2129  PSS Telemetry Rockhampton to Walaroo     FAIL  NM00000236
1494  PSS Telemetry Rockhampton to Westwood    FAIL  NM00000149
2126  PSS Telemetry Rockhampton to Wycarbah    FAIL  NM00000236
2126  PSS Telemetry Rockhampton to Wycarbah    FAIL  NM00000236
118   router Duaringa to Rockhampton           FAIL  NM00000011
5     trunk Blackwater to Rockhampton # 1      FAIL  NM00000000
6     trunk Blackwater to Rockhampton # 2      FAIL  NM00000000
1219  trunk Blackwater to Rockhampton # 4      FAIL  NM00000121
4     trunk Rockhampton to Walaroo             FAIL  NM00000000
1216  trunk Rockhampton to Windah # 1          FAIL  NM00000121
```

```
VF Failures (common between window 1 and  window
VF Failures (common FAILS from window 2)
VF Failures (common  Fails from window 1)
VF Failures (from window 3)
```

```
              MULTI SEGMENT HIT ON A BRANCHING E1
Window 3
              do not proceed if any entries
circuit
1221  omni Rockhampton to Windah        FAIL      10
```

```
Window 4
                                 circuit  circuit
1513  UTC ROK LOOP 02/14         5        1216  FAIL
1513  UTC ROK LOOP 02/14         5        1219  FAIL
1545  PSS ROK LOOP 06            6        1216  FAIL
1546  PSS ROK LOOP 07            6        1216  FAIL
1547  PSS ROK LOOP 08            6        1216  FAIL
1548  PSS ROK LOOP 09            6        1219  FAIL
1549  PSS ROK LOOP 10            6        1219  FAIL
1585  ECO ROK Blackwater         1221     0     FAIL
1586  831-565                    1221     0     FAIL
1602  832-559                    1221     0     FAIL
1674  LOW SPEED DATA             1221     0     FAIL
1675  START SIGNAL 1             1221     0     FAIL
1676  START SIGNAL 2             1221     0     FAIL
2003  QRNFL                      1221     0     FAIL
```

Fig. 10. Automated service status report affected by multiple link failures

Fig. 10 is a report of service status after modelling multiple link failures in the model.

This report allows the network engineer to determine the extent of the impact they will have on the integrity of service delivery.

The top left window indicates (3) three separate bit stream failures selected at random in the network. The top right window lists the amalgamated router services that require testing for co-location failure as a result of the modelled impact. The bottom left window indicates multiple bit stream failures on the PDH common mode omnibus. The bottom right window succinctly lists the mission critical signalling system failures that will occur as a result.

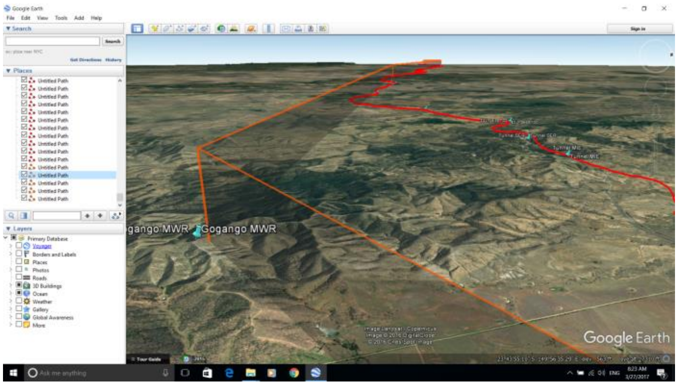


Fig. 11. Spatial information with Google Earth

The model uses common applications to display the data in a variety of formats. VBA coding within the graphic model environment is able to correlate data and export from the model to e.g. Google Earth application (Fig. 11). The data is emblazoned onto a GIS backdrop. Red colouration is assigned to a bit stream in a fibre optic medium and the orange elevated curtain is assigned to a microwave medium. The modelled data approach bypasses the need for staff members to churn over a multitude of separate circuit diagrams in order to ascertain the extent of impact network disruption will have on rail traffic. In order to evalute the impact, the model performs coded analysis on main and protection paths of voice delivered services and indicates visual analysis where necessary for routed data traffic services. The model's unique blend of logical analysis and visual analysis is seldom found in commercial solutions.

Discrepancies in latitudinal and longitudinal data are easily detected when exported onto the Google Earth backdrop.

Using in house common applications avoids the big dollar spend associated with commercial solutions.

Note the versatility available by using simple, readily available common applications to achieve quality reports and control of the modelled network and all the while avoiding the big dollar spend associated with commercial solutions.

V. OBSERVATIONS AND CONCLUSIONS

The following observation and conclusion remarks can be drawn from the paper:

- Unlike their domestic cousins, rail utility networks are deployed with large amounts of backup paths, in order to maintain an industrial level of connectivity for service reliability.
- The overarching transportation layer of modern networks is ultimately a reconfigurable switched network, which facilitates a degree of control over underlying routed networks utilizing these predetermined pathways of the transportation domain. The predetermined paths in the switched network are controlled by cross connections at a bit stream level or more recently, cross connections at an optical level. Ostensibly, either format is readily able to be manifested by this model.
- Modelling network payload using common application has been thoroughly explored using the techniques described in this paper. The modelled techniques herein offer distinct advantages over commercial grade solutions by way of low cost, rapid implementation, easy access, and customising flexibility.
- The model is able to auto generate a plethora of diagrams and reports from underlying data, and exhibit the information in a timely manner, most suitable for engineering staff to disseminate and understand.
- The impact upon traditional drawing regimes is significant; the draftsman's eye for detail has evolved into the coding domain of the telecommunication artisan developer.

ACKNOWLEDGMENT

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