Framework and Methodology for the ITU World Terrestrial Transmission Map Project

There is not currently a map of the world's terrestrial fibre optic transmission networks. The existence of such a map would be an important reference work, and the indicators which can be created from the map are useful and meaningful indicators of broadband supply. The scope of this ITU project is to research, process and create maps of core terrestrial transmission networks for the following ITU regions: Arab region, CIS region, Asia Pacific region, North America region, Latin America and the Caribbean region, and the Africa region. The maps will be published in various ITU documents and reports, and in 2D and 3D web map formats. The indicators derived from the map can be published through the map itself and in various ITU publications, and being supply-side indicators will augment the existing set of ITU indicators for broadband usage and penetration.

1. Introduction

Core transmission networks are the essential underpinning of broadband access networks. Broadband is the delivery of Internet Protocol (IP) connectivity (at speeds of 256 Kbps or more in one or both directions), and all of the content, services and applications which consume this bandwidth. The IP connectivity required to deliver these content, services and applications is achieved at certain Tier 1 points of presence (POPs), which are physically located in buildings in certain places. Likewise, web content and services are stored or delivered through web servers which are physically located in other buildings in certain places.

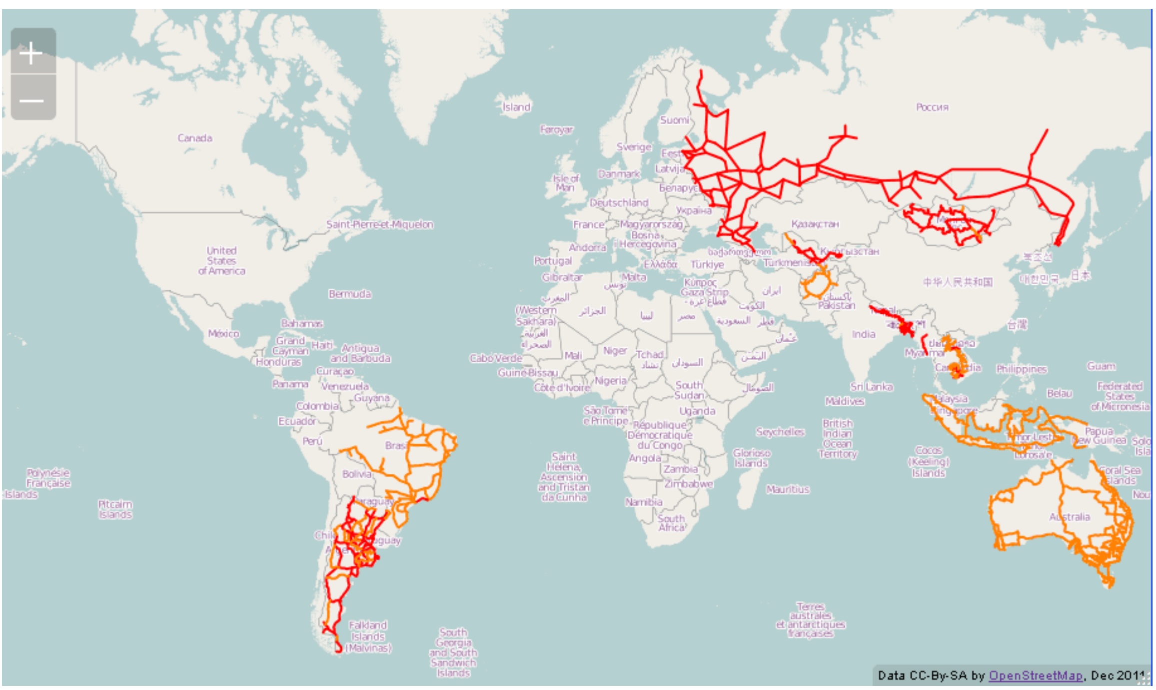
The essential underpinning of a broadband access network therefore is a core transmission backbone network that connects to these Tier 1 POPs and has sufficient capacity to deliver the amount of bandwidth required by the populations (customers) it serves. Providing an entry level 256 Kbps broadband service to hundreds, thousands or millions of customers requires a backbone transmission network with sufficient capacity to do so. Each time an operator increases its broadband service from 256 Kbps to 512 Kbps, 2 Mbps, 43 Mbps and so on, this in turn escalates the capacity requirements of the transmission backbone network.

This map project itself demonstrates precisely this. The web map application and the content provided in it will be located on ITU servers in Switzerland. Whenever a user accesses the map, the content is requested and delivered through a series of transmission networks from the web server in Switzerland to the user's computer, tablet or smartphone, wherever they happen to be in the world. If the file size of the web map is too large, users without sufficient broadband will not be able to use it.

As an infrastructure, broadband has been compared to canals, roads, and railways of previous times. It has been recognized as a critical enabling infrastructure which contributes to economic growth and social enrichment. But we couldn't tell that much by counting the number of canal boats, cars, or trains in previous times. We couldn't really tell what was going on by the volumes of passengers or freight which were transported by these networks. What we need to know is whether or not a particular country, city, town or village was reachable by one of these networks. So it is with broadband. We can know what broadband access networks operators have deployed in a country, and what throughput speeds these are capable of. And we can know how many subscribers there are, and what the level of penetration is. But in the quest to provide universal broadband, it is important to know whether or not a country is connected to the global information highways, within that country which cities, towns and villages can be reached, and whether or not these transmission networks have sufficient capacity for the population it serves.

2. Scoping

In October 2011, the ITU published the Broadband Atlas, which shows a number of broadband indicators as 3D extruded country polygons using the Google Earth javascript plugin (http://www.itu.int/ITU-D/treg/atlas/broadbandatlas.asp). A short scoping exercise was then conducted during December 2011 to explore and test the feasibility of producing a world terrestrial transmission map. A sample offline web map was produced (see below). Using only information that was readily available in the public domain, the networks for 19 operators in 13 countries were digitized and added to this initial map. In this coping exercise, over 1,000 fibre optic links and nodes were processed, representing in total some 186,658 route kilometres of fibre network infrastructure.



If this map layer were to be shown against a base map layer of population density, it is possible to compare the location of transmission networks against the population they serve. This picture of supply can deliver important insight into the uptake and penetration of broadband services across different countries, and within countries at the sub-national level as well. This observation is quantifiable in the ‘Percentage of population within reach of a transmission network’ indicator which is outlined below.

3. Audience

A regional or world transmission map and its underlying database have utility for three main consitituencies: i) the general public and interested parties, ii) for the improvement of network operators, regulators and administrations, and iii) for the work of expert technical organizations within or associated with the ITU. A clear policy needs to be put into place to determine and control what level of detail is made available to each of these different constituencies: 1) available to the public, 2) available to ITU members (TIES restricted and password protected), and 3) available to expert technical organizations.

This policy can be controlled through the format in which the map and its underlying database is made available, and the level of disclosure can be addressed as part of a formal validation process. A map is a 'picture' of data, and by using scale and format the type and level of data which is disclosed can be carefully controlled. It is not that necessary, useful or even that interesting to make publicly available the technical detail in the underlying database. For example, it is not necessary to publicly disclose the co-ordinates of network nodes, the individual link capacities (STM-16), or number of optical fibres (24) per cable in an operator's network. Some expert organizations might have a need for this level of information in the course of their technical work, but this level of information does not belong in the public domain. A mistake on this point will result in the release of detailed technical data irrevocably into the public domain, some of which may be confidential and awaiting clearance to be published.

4. Research

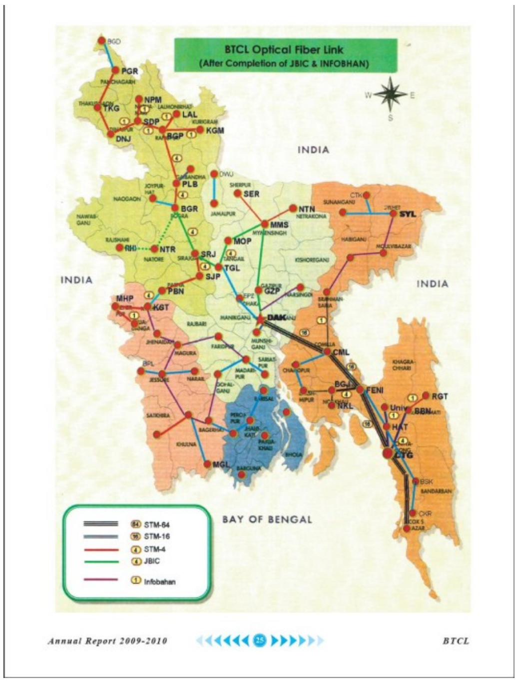
In order for a transmission map to be accurate and meaningful, a fairly deep consistent level of technical detail is needed for the links and nodes in the networks that it shows. The accuracy of a map is only as good as the source material which is researched or provided. The world map will be researched region by region, competing one region before moving on to the next on a rolling basis. Unlike maps of physical features such as roads, towns or coastlines which can be derived from aerial photographs or satellite imagery, telecommunication transmission networks are 'invisible' in the sense that exist as microwave radio frequencies, cables which are buried under ground, or are submerged beneath the sea.

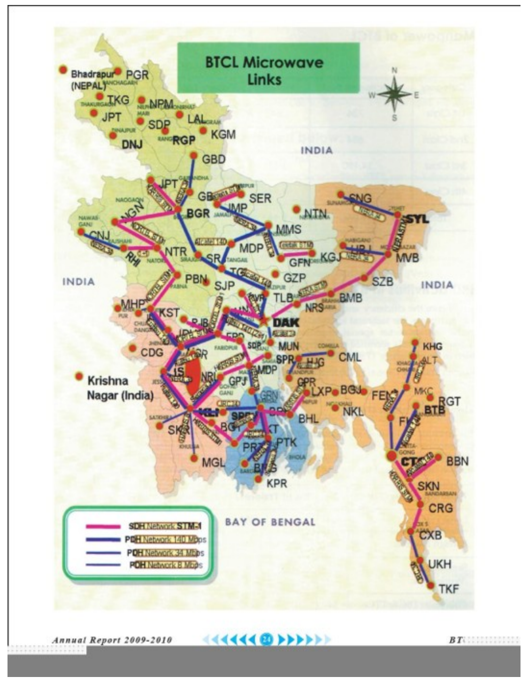
The routing and extent of transmission networks in a map cannot be estimated, interpolated or forecasted, and can be unforgiving in its requirement for accuracy to the tiniest detail. The information contained in a telecommunication transmission network map must therefore be sourced from the operators which own these networks, from a range of primary and secondary sources. Unlike a tabular dataset of country subscriber statistics for example, a map of networks will never be 100 per cent complete, 100 per cent accurate, or 100 per cent up-to-date, and it is only therefore possible to be produced on a 'best-effort' and 'as-is' basis.

4.1 Primary sources: An official request for information (RFI) document is drafted outlining the purpose of the project for operators, indicating what level of detail is required, and what format the data is to be published in, and providing contributors with access to the (TIES password) map which is under development so that they can see how the information is used, what. The request for information will provide sample format in which we ask the information to be provided.

4.2 Secondary sources: On average around 25 – 40% of the data is readily available in the public domain, from operator websites, annual reports, company presentations, and presentations at industry conferences. The amount which is available in the public domain varies considerably between countries, for some countries nearly all of the network routing information can be sourced from the public domain, and in others none is available. Much of the data may already exist in presentations made at ITU workshops and events, some of which may not be publicly available (restricted to TIES users).

Example: Bangladesh Telecommunications Co Ltd (BTCL)





Source: Bangladesh Telecommunications Co Ltd (BTCL) 2009/2010 Annual Report
http://www.btcl.gov.bd/annualreport/BTCL_Annual_Report_2009_10.htm

4.3 Partnership. Researching a world terrestrial transmission map is a very considerable undertaking, and it has not been done before. There is so much work to get through that it does not make sense to duplicate the efforts of other organizations. A number of organizations do already research and produce transmission network maps for particular countries or regions, for various technical reasons. Wherever possible, it would be advantageous to seek partnership with these organizations, to seek permission to display their network maps work through the ITU world transmission map. It is important to bear in mind that these partner organizations may have certain confidentiality, security or commercial obligations preventing them from releasing some or all of the information that they may have collated, and should only be asked to provide the level of detail which they are comfortable or permitted to provide. In line with standard web map practice, the source, attribution and if applicable copyright of the content provided in these works should be properly acknowledged and credited.

4.4 Feedback Loop. One of the best methods of gathering information is when operators provide feedback on maps which have been published. Both positive and negative feedback is useful. Similar to the first charts of the oceans that were made by sea-faring explorers, the charts were improved immeasurably by the sailors that followed afterwards who would report back on errors, inaccuracies, and provide further levels of detail on coastlines, harbours, sea-depths, hazards, and so on. This process continually improved the accuracy and usefulness of the charts for all the sailors that followed after them. For the ITU world transmission map, the first step in helping to create this virtuous feedback loop is the initial validation process outlined below. As a version of the map will then be made publicly available it is likely to gain the interest of operators and other interested parties who will use it, and who will hopefully be willing to point out errors, provide updates and so on.

5. Production: Processing, Storage, and Publication

The goal of a map as a reference work is to process source material into a consistent, legible, and standardised format so that it is easily understood and directly comparable across the world. The workflow process is that information is researched, source material is stored, processed in a GIS software into vector files and a database, rendered into a draft working map, validated by the competent authority, and then published into the public domain.

5.1 Store source data. Operators produce and publish maps or diagrams of their transmission networks in a wide variety of formats. The original source material which is used is stored in folders within a database, so that the provenance of the data can be checked at any time, and so that successive versions of an operators map can be stored and updated over time.

5.2 GIS processing. The source material is digitized using GIS software into vector data (lines for transmission links, and points for network nodes). Each line or point is given a unique identifier (Id) at the time that it is drawn into the map. The level of technical detail provided in source material is variable. Some operators provide maps in great technical and cartographic detail, whereas others tend to be more topological diagrams. In the digitizing process, the routes of networks are drawn into the map as lines of best fit between nodes. Where there is more than one operator with network infrastructure running along a particular route between two nodes, lines are drawn in parallel at a set distance in exploded view fashion for clarity. For main hubs in capital and main cities a single node is drawn, and for intermediary nodes in towns and cities along the way nodes for each operator placed on the line at the vertex.

5.3 Database. For each line or point which is drawn on the map, a corresponding entry is made against its unique identifier (Id) into an Excel dataset, recording as much technical information about the link or node as is provided in the source material. The data which is entered is operator, start node, end node, operational status, equipped capacity, date and so on. All or part of this dataset can then attached to the vector file through the geodatabase sitting between the map document and Excel dataset in order to efficiently manage and render the map into an image.

	A	B	C	D	E	F	G	H	I
1	Id	Country	Operator	Region	From_	To_	Status	Type_	Distance (Km)
535	100285	Bangladesh	BTCL	Asia Pacific	Jessore	Khulna	Operational Fibre	1	66.91
536	100286	Bangladesh	BTCL	Asia Pacific	Khulna	Satkira	Operational Fibre	1	49.50
537	100287	Bangladesh	BTCL	Asia Pacific	Khulna	Bagerhat	Operational Fibre	1	30.77
538	100288	Bangladesh	BTCL	Asia Pacific	Khulna	MGL	Operational Fibre	1	81.82
539	100289	Bangladesh	BTCL	Asia Pacific	Bagerhat	Gohal Ganu	Operational Fibre	1	41.44
540	100290	Bangladesh	BTCL	Asia Pacific	Gohal Ganu	Madaripur	Operational Fibre	1	35.43
541	100291	Bangladesh	BTCL	Asia Pacific	Madaripur	Faridpur	Operational Fibre	1	61.68
542	100292	Bangladesh	BTCL	Asia Pacific	Madaripur	Sariatpur	Operational Fibre	1	23.56
543	100293	Bangladesh	BTCL	Asia Pacific	Bagerhat	Perojpur	Operational Fibre	1	29.75
544	100294	Bangladesh	BTCL	Asia Pacific	Perojpur	Barissal	Operational Fibre	1	43.72
545	100295	Bangladesh	BTCL	Asia Pacific	Comilla	Chandpur	Operational Fibre	1	58.06
546	100296	Bangladesh	BTCL	Asia Pacific	Chandpur	Ashmipur	Operational Fibre	1	31.19
547	100297	Bangladesh	BTCL	Asia Pacific	Ashmipur	Alipur	Operational Fibre	1	30.16
548	100298	Bangladesh	BTCL	Asia Pacific	Alipur	Feni	Operational Fibre	1	30.64
549	100299	Bangladesh	BTCL	Asia Pacific	Alipur	Noakhali	Operational Fibre	1	12.44
550	100300	Bangladesh	BTCL	Asia Pacific	Comilla	Brahman Baria	Operational Fibre	1	43.55
551	100302	Bangladesh	BTCL	Asia Pacific	Habiganj	Moulvizbazar	Operational Fibre	1	36.93
552	100301	Bangladesh	BTCL	Asia Pacific	Brahman Baria	Habiganj	Operational Fibre	1	56.78
553	100303	Bangladesh	BTCL	Asia Pacific	Mouvizbazar	Sylhet	Operational Fibre	1	43.20

5.4 Map Style. By attaching the vector files to the Excel dataset, lines can be drawn according to the equipment type (line colour is determined for microwave, buried fibre, aerial fibre), operational status (line style is solid for operational, dashed for under construction, dot-dashed for proposed), and equipped capacity (line weight, set either to 1 point or 2 points). Each line or point in the map is then rendered according to the code which gives it a certain style. The maps are given a uniform style, in which the thickness, colour, style and font of lines, points and labels is determined. This style guide to be developed is written down and uniformly applied to all maps.

5.5 Production. One the map has been styled in the GIS software, it is then capable of being exported into image file(s), either as static files (JPEG, PDF) for inclusion in documents, or in web map format (tilesets for 2D, KMZ files for 3D). Before this is done, the dataset is sorted (filtered) by the validation code (see below) in order to determine whether a particular link is to be included or excluded in the version required of the map which is being outputted. Only the data which is at the validation stage is included.

6. Validation

6.1 How to Validate. The transmission networks shown in the map belong to networks operators. The operators are therefore the only organisations which are capable of validating (or invalidating) maps of their own network infrastructure. In terms of the physical network infrastructure which is deployed, the map is either right or wrong. If the source material used is therefore provided by an operator, either as primary data supplied directly by the operator, or secondary data sourced from a company publication (presentation, annual report and so on) it must therefore be valid in the same way that subscriber numbers published in annual or quarterly reports would be. In the case of non-response from a network operator regarding information which is readily available in the public domain, it may be possible that regulatory authorities are able to validate or invalidate the information.

6.2 Timeliness. Data which is correct today may well become incorrect in years to come, it will go past its ‘sell-by date’. Transmission networks are constantly changing over time, as network which is under construction enters service, new routes are added, network which is planned or proposed goes into deployment, and network plans change. It is important to monitor this operational status as proposed network plans may change five or six times before it is actually built. In general, fibre optic network which has been deployed is permanent unless it falls into disrepair, is destroyed or exits service for some other reason. It is therefore important to date the information for each piece of network infrastructure, with the date it was processed and as far as possible with the date it entered service, and then to update this as new information comes to light replacing the previous information.

6.3 Disclosure. Some operators are willing to provide information of their networks, to varying levels of detail, and others are not for a variety of competitive, commercial and security reasons. These are legitimate concerns which need to be respected: the network maps are of their physical network infrastructure. In some cases operators may not permit the disclosure of their network routing maps, but they may already publish or be willing to provide other metrics such as the total number of route-kms in their network. Network operators should only be asked to provide the level or granularity of information which they are comfortable and willing to provide. Neither the map nor the database should contain any information which is regarded by the operator as confidential. This is an important step that the validation process should include. Information which is shown in the TIES version of the web map is treated as an official working document, and is subject to TIES terms of use. Furthermore, the ITU should have the ability to retract any data at any time if it is ever asked to do so (which is possible, being fully aware of the terms of use different web map APIs).

6.4 Validation and clearance procedure: It is important to put in place a formal validation procedure to address these concerns of correctness, timeliness and confidentiality. The Excel dataset for each region contains a column called ‘validation’. This validation column contains a numeric value indicating the validation status of each individual piece of network infrastructure. The database is then filtered by this column in order to show subsets of the following status:

1) PROCESSED DATA. All source data which has been processed, and has been inputted into the TIES web map for checking and validation.

2) REQUIRES VALIDATION. Data which may contain confidential information, was sourced from a restricted document (for example on TIES), or may come from a potentially unreliable publicly available source (such as a third party). Operator is asked to provide clearance that the information is correct, up-to-date, and is not confidential.

3) VALID, PENDING PUBLICATION. Data which was sourced from an authentic, reliable publicly available source (company website, annual report, presentation, or other publication). Operator is given the opportunity to check prior to publication.

4) CLEARED FOR PUBLICATION. Data which has *either* been sourced from reliable publicly available source (company website, annual report, presentation, or other publication), *or* has been checked and cleared for publication by the competent authority (operator, regulator, administration, or regional organization).

The best authority to manage this validation process is through the ITU Regional Offices, who can write to members or operators to check or validate the information contained in the map. The process would be that the ITU Regional Office is asked to notify the operator that the map of their network has been added to the regional map, invite them to log in to TIES to check and validate the network, and send a confirmation that they have no objection for this information to be included.

7. Indicators.

Once the networks for a country have been digitized into the GIS software, it is possible to produce statistical indicators from this data. These indicators can be produced at the country or regional level, and produced in annual intervals in order to track change in the deployment of terrestrial transmission networks over time. A full definition and methodology of these indicators is provided.

1. Fibre optic cable length (Route kilometers)
2. Node locations
3. Equipment type of terrestrial transmission network
4. Network capacity per channel (bit rate)
5. Number of optical fibres within the cable
6. Operational status of transmission network
7. Percentage of population within reach of transmission networks

8. Web map.

The regional, and eventually the world, transmission map will be displayed in a web map published on the ITU website. The transmission map will be published in 2D and 3D web map formats, and will serve as an insightful base layer to map layers of other ITU indicators which can be added on the top. The 2D web map will be mobile-ready so that in addition to supporting desktop web browsers, the maps are accessible in the mobile browsers of smartphones. The 3D version of the map will use the existing ITU Broadband Atlas published in 2011 which uses the Google Earth plugin, and will be developed as required to accommodate.

For the reasons outlined below, the web map will use open source software which does not have any restrictions with regard to licensing, fees or terms of use. There will be two versions of this map, published on separate html web pages. One map will become an official ITU working document and will only be accessible to ITU members by password protection through TIES. The other map will be made public, and will be published in the public domain in line with the validation procedure.

8.1 Server arrangement. The web map will be hosted on an ITU server, which will contain the html pages containing the maps, the components of the web map, and the processed map files (tilesets, and KMZ files). The hosting and server arrangements need to be finalized.

8.2 Choice of Web Map API. The web map is built using a Javascript API (application programming interface). There are both commercial and open source javascript web mapping APIs. ESRI Javascript API, Google Maps, Google Earth plugin, Bing, and Yahoo are examples of commercial APIs, whereas OpenLayers is an example of an open source web map API. For the reasons outlined below, OpenLayers is used as the best format for the construction of the web map.

First, in proprietary web map APIs, the source code is hosted on the providers server, is not readily accessible for customized programming, and regularly changes as new functions are added and other functions are deprecated (removed). If the map which is built is dependent on functions which become deprecated in the future, it will cease to work unless the map is updated. With OpenLayers, a customized version of the source code can be built and stored on the server where the web map is implemented. This means that deprecated functions are not affected by subsequent releases, and also speeds up the map processing time because the source code is referenced locally.

Second, the terms of service are different between different APIs. Commercial APIs may charge fees for certain types of usage (and this may change in the future), and are also subject to certain terms of use. For example, any content which is used in the Google Maps or Earth plugin for example is subject to the terms of usage http://code.google.com/apis/maps/terms.html which notably include that:

11.1 Content License. Google claims no ownership over Your Content, and you retain copyright and any other rights you already hold in Your Content. By submitting, posting or displaying Your Content in the Service, you give Google a perpetual, irrevocable, worldwide, royalty-free, and non-exclusive license to reproduce, adapt, modify, translate, publicly perform, publicly display and distribute Your Content through the Service for the sole purpose of enabling Google to provide you with the Service in accordance with Google's privacy policy.

The other commercial APIs have similar terms of service, which are not therefore compatible with any duties of non-disclosure which may pertain to information which is in the process of being validated, mean that information cannot be retracted once it has been displayed through the web map, and that information which has been displayed has been put forever and irrevocably into the public domain.

8.3 Format of Web Map Content. Content can be displayed in a web map in one of two basic ways, either in a vector data format (which contains co-ordinates and may contain other technical data), or in a raster format (picture files). The raster format will be used to display terrestrial transmission lines, using the tilesets for displaying in the 2D web map, and a raster KMZ file in the 3D web map. The ITU Broadband Atlas displays files in KMZ format. KMZ is simply a zipped KML file, and can contain either vector or raster data, or both. The extruded 3D country map files use vector KMZ to display country polygons, whilst the basemap layer uses raster KMZ to display images (called ‘superoverlays’).

Vector KML: coordinates used to draw points, lines or polygons

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  <description>Unknown Line Type</descri
  <styleUrl>#line1</styleUrl>
  <LineString>
    <coordinates>
      -58.2401390000,-32.4877890000,0
      -58.2203857214,-32.2584738686,0
      -58.3000000000,-31.9833330000,0
      -58.3166026922,-31.8308428871,0
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      -58.0172610052,-31.3604488074,0
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  </LineString>
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  <LineString>
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  </LineString>
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<Placemark>
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Raster KML: images laid on top of map

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    <href>Basemap_ITU_Logo\basemap_kmz_L1_0_0.png</href>
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    <south>-89.9999999999991500</south>
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      <south>-89.9999999999991500</south>
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    </Lod>
  </Region>
  <GroundOverlay>
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Note that in the example above, in the vector KML format the actual co-ordinates of each node or vertex in a line are necessarily included in order to be able draw the line. This vector KML format is not suitable for in this project for several reasons:

1) we do not wish to release the co-ordinates of nodes or vertices into the public domain (this is not necessary or desirable),

2) with unrestricted zooming this would enable the user to locate actual buildings, if the maps were drawn to that level of accuracy (which they are not, and so the map loses accuracy at these scales),

3) web browsers have a restriction on the number of points or lines in a vector file which can be processed. The more points or lines there are, the longer the map will take to load. The upper limit varies, but once it has been reached the map will fail to load altogether. In order for the web map to successfully load on mobile devices, the payload of the map needs to be small as possible. This project will easily exceed this technical restriction within the first region,

4) KML has limited styling options available, it does not for example support dotted or dashed lines.

8.4 Scale ('Zoom Levels'). The transmission map will show long-haul transport networks and nodes, rather than street-level metro network data. Web map APIs have up to 18 (for eg OpenStreetMap) or 22 (for eg Google Maps) zoom levels, which is sufficient to show street level information and identify individual buildings. We recommend that zoom level 9 is sufficient to show the maximum level of detail of long-haul networks. If you were to be able to keep zooming in, the user would therefore see straight lines which apparently run through peoples back gardens. The map therefore loses its accuracy when you zoom in beyond the scale the map was drawn at. The best solution therefore is to restrict the number of zoom levels to which the user can zoom, although this control is not possible in the Google Earth plugin. The solution for the GE plugin is to use a raster format so that the lines just get progressively more blurry as you zoom in, and/or to make the file fade out as the user zooms in.