IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 11, Issue 5, Ver. I (Sep.-Oct .2016), PP 77-83
www.iosrjournals.org

Building Telecommunication Facilities for Railway

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Abstract: *Train has become a favoritetransportation in Indonesia, especially, in the near end of Ramadan. Thousands of people leaving fortheir home villages to meet and see their families and relatives. Therefore, a good and reliable railway communication system has to be considered as one of vital facilities in transportation business. This paper discussed about building telecommunication facilities for rail way communication system using Synchronous Digital Hierarchy ring network. Some services with different platforms such as data communicationand voice communicationwere made for signaling train operation and train dispatching among drivers personals, way stations and train control center office.Forpassengers'comfort ability, Ethernet services such as Wi-Fi, passenger display information, public address were also madeeither in a railway station or train in motion. All those services mentioned were provided by SDH add-drop multiplexer equipment which support multi service provisioning platform and TETRA radio network. Conclusion could be drawn that the railway communication system was completely build and tested successfully in small scale test bed.*
Keywords:*Wi-Fi, TETRA, train dispatching, Ethernet, SDH*

I. Introduction

In modern life, nowadays, not only exchange of information in many ways but also movement of people from one place to another by any means of transportation occur every moment. As the mobility of people increase, in this case, a transportation has become an important role in our life. Among of existing transportation, train has become a popular one for many people in many parts of the world. A safe and comfort train are of course of what the most passengers want. Good train operation and management aspects will insure passenger's satisfaction. Railway communication system play important role to fulfil those aspects mentioned above. This paper discussed about building telecommunication facilities for railway itwas basically made of three main networks: optical ring Synchronous Digital Hierarchy (SDH) network for transporting large bandwidth digital signal,PDH multiplexer network foruser's access and radio network for train dispatching. Nowadays, safe and reliable communication system become a challenge faced by railway operators in order to provide good services to passenger and to overcome the increase of traffics (Aguado et al., 2005).Some services with different platforms such as data communication and voice communication were required for railway signaling and railway telephone private network. Therefore SDH based telecommunication infrastructure network should support number of interfaces such as V.11, V.24, V.28 and G703to do the jobs.

II. Research Method

Building telecommunication facilities for railwayinvolved two main phases namely design phase and implementation phase. In the designphase, design criteria, technical requirement and specification should be defined according to the Indonesian government regulation PM No.11- 2011.

2.1 Design criteria

General design criteria for building railway telecommunication facilities are as follows;

a) Signalling, telecommunication and power supply system shall operate properly and easy to be integrated with existing system.
b) Design shall assure fail-safe operation so that it can support fail-safe configuration for signallingand telecommunication system individually.
c) Signalling, telecommunication system shall be reliable due to high loading condition for long life operation for at least ten years.
d) All equipment shall be supported with availability of spare parts for at least ten years.
e) System reliability shall be counter measured with existing environment where the system will be installed.

2.2 Technical requirement

Technical requirement for building railway telecommunication facilities is described in Table 1.

Table 1. Technical requirement

No	Items	Design criteria
1	Fiber Optic (FO) communication system	- FO communication equipment shall support all services such as data communication between electric signaling equipment and telephone between stations. - SDH based Signalling and telecommunication backbone shall use areal single mode FO cable with 24 cores and confirm recommendation of ITU-T G.652 D. - FO Cable shall All Dielectric Self Support (ADSS) type and operate for all wave length between 1260 and 1625 nm. For instance 1310 nm and 1550 nm are also included in the range. - FO cables shall operate at temperature from 10 to 50 degrees celcius. 6 out of 24 cores and have to be dropped in local case and the rest shall pass through. - Tecommunication equipment shall be based on Synchronous Digital Hirarchy (SDH) ITU G.707 Standard. - STM-1 for short haul and STM-4 for long haul transmission - can be configured for Add Drop and Cross Connect application with different bit rate such as 64 kbps basic rate signal, 8 Mbps signal etc from different input to different output. - support regeneration for long haul transmission.
2	SDH Equipment	- Shall provide Ethernet physical layer carrier to support Asynchronous Transfer Mode (ATM) application.
3	Data & Voice Transport Modul (multiplexer)	- support various type of interfaces such as 2W, 4W E&M, nx64 kbps, ISDN, G.703, V11, V24, V35 and can provide more than 4 analog or digital channel.
4	Optical Distribution Frame (ODF)	- Optical Distribution Frame used for FO cable termination.
5	Voice Recorder	- Telecommunication system shall be equiped with digital voice recorder at every station.
6	Telephone system	- Shall provide voice communicationused for railway operational. - Telephone system comprise Private Branch Exchange (PABX) which is integrated with railway operational and management. - Telephone console is put in train dispatcher office to communicate with adjecent stations, railway crossing, and post telephone.
7	Power supply	- Main power supply use main power from Indonesian electricity accompany (PLN) grid system. - Back-up for main power system shall be provided.
8	Grounding system	- Shall protect all equipment from lighnting - Grounding value shall be less than 1 Ohm.
9	Equipment Lay out in side building	- Building layout design shall consider ventilation aspect for air circulation. - Cable layout in the room shall consider comfortability of the cable, protected and easy to rich for maintenance purpose.
10	Terestrial Trunked Radio System (TETRA)	- Air interface for voice communication shall support Direct Mode Operation (DMO) and Tetra Mode Operation (TMO). - Shall support speech, data (circuit mode, packet mode), short data service etc. - Trunked Radio shall be located within railway service area according to engineering calculation.

2.3 Optical communication system design

Optical communication systemis basically ring SDH network using fiber optic (FO) link as transmission medium. FO link communication design is an activity where balance between available opticalpower and distance of FO link has to be considered. Like other system,it is necessary to define performance criteria and decide how this criteria will be fulfilled. Capability calculation of a system to perform will depend on many elements. The following is a list of basic element used to determine performance criteria of an optical transmission system;

2.3.1Loss factor has big influence due to the overall system performance.

- FO maker usually provides cable loss factor in dB per kilometer. Total cable loss is calculated based on distance which is multiplied by loss factor. In this case, distance is total length of cable run, not distance on a map.FO used for transmission is normally single mode type cable with loss factor between 0,25 @1550 nm and 0,35 @1310 nm dB/km. Single mode FO used is for an available transmitter. The transmitter use a LASER with various different output powereither for long reach or short reach criteria
- Basically, there are two types of transmitter used in FO system: Light Amplification by Stimulated Emission of Radiation (LASER) and Light Emitting Diode (LED). LASER is available with three variants:high for long reach, medium for medium reach, and low for short reach. Whereas, LED exists with high power and used for single mode FO. FO transmitter is usually indicated by light power at output connector expressed in dBm, for instance, -5 dBm etc.
- The capability of a receiver to see light source called receiver sensitivity, requires amount of light, for instance,-28 dBm. An optical receiver is also called a light detector.
- Number of splices, there are two types of splices, they are mechanical and fusion splices. Generally, mechanical splices have about 0.7 to 1.5 dB per connector whereas fusion splices exhibit 0.1 up to 0.5 dB

per splice. Therefore, fusion splices are favourable due to its small loss.

- Power margin is another important factor to be considered. This margin is required when power level decrease due to FO aging. In FO design, 3 up to 10 dB is normally added to loss budget margin

2.3.2 Estimating total link loss

There are many ways to determine power required for FO link. The simplest way is using *Optical Time Domain Reflectometer* (OTDR). Doing this measurement, true total loss of FO link will be known. But there are two other alternative ways to estimate power required for the FO link, as follows;

1. Estimating total FO link loss if the length of FO cable and its loss variables are known.
2. Estimating maximum distance of FO cable if optical budget and its loss variables are known

Loss variables are coming from connectors, splices and cable attenuation per kilometer. Therefore in calculation one can make good estimate of such losses for each variables. In this case we have to make approach for worst condition to guarantee sufficient power for FO link. Table 2. shows information related to loss which is generally accepted in calculation whille Table 3. Gives IEEE recommendation for maximun distance of FO cable and Ethernet standard with various data rate.

Tabel 2. Loss of FO cable, connectors and splices

Types of Fiber Optic	Wavelength (λ)	FO attenuation /km	Connector loss	Splice loss
Multi mode 50/125 μm	850 nm 1300	3,5 dB 1,5 dB	0,75 dB 0,75 dB	0,1 dB 0,1 dB
Multi mode62,5/125 μm	850 nm 1300	3,5 dB 1,5 dB	0,75 dB 0,75 dB	0,1 dB 0,1 dB
Single mode9 /125 μm	1310 nm 1550 nm	0,4 dB 0,3 dB	0,75 dB 0,75 dB	0,1 dB 0,1 dB

Source: TIA/EIA specification and other industry.

Tabel 3.IEEE specification for maximum FO distance

Standard	Data Rate (Mbps)	Cable type	DistanceIEEE Standard
10 Base-FL	10	850 nm Multi mode 50/125 μm atau 62,5/125 μm	2 km
100 Base-FX	100	1300 nm Multi mode 50/125 μm atau 62,5/125 μm	2 km
100 Base-SX	100	850 nm Multi mode 50/125 μm atau 62,5/125 μm	300 m
1000 Base-SX	1000	850 nm Multi mode 50/125 μm 850 nm Multi mode 62,5/125 μm	550 m 220 m
1000 Base-LX	1000	1300 nm Multi mode 50/125 μm atau 62,5/125 μm 1310 nm Single mode 9/125 μm	550 m 5 km
1000 Base-LH	1000	1550 nm Single mode 9/125 μm	70 km

Source: IEEE Standard

The followings are formulas to calculate link loss and FO length;

Link loss=[FO lenght (km) x FO attenuation per km]+ [splice loss x number of splices] + [connector loss x number of connectors]+ [safety margin]

FO Length =([Optical link budget]- [link loss])/[FO attenuation/km]

FO Length ={[(min.TX PWR)- (RX sensitivity)]- [splice loss x number of splices]–[connector loss x number of connectors]- [safety margin]} ÷[FO attenuation/km]

2.3.3 Optical link budget calculation

In this optical link budget calculation, assume FO cable used is1310 nm, 9 /125 μm single mode FO refer to Table 2.And design scenario was described as follows;

"Ring SDH network consist of four stations represented by ADM equipment's as shown in Figure 1. Distance between two stations (ADM A and ADM B) is about 13 km based on map distance. Assume that main communication devices at each stations are SDH Multiplexers connected with FO cable via optical communication interfaces. Based on walkingroute, actual distance between between two stations is 16 km. And assume there are no other devices installed along the FO link".

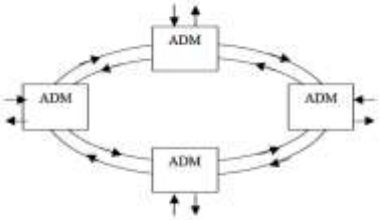

Figure 1. Ring SDH network

Technical specification of SDH equipment used for this design is as follows;
Bit rate nominal : STM-1 155.520 kbit/s
Operating wavelength range : 1310/1550 nm
Distance : 20 km
Type of FO : G.652
Transmit power : - 8 dBm
Range of link loss : 10 up to 28 dB
Minimum sensitivity level : - 34 dBm
Interfis E1 Tributary
Bit rate : 2.048 kbit/s ±50 ppm
Coding : HDB3
Impedance : 75Ω unbalanced or 120Ω balanced
Standard : ITU-T G.703, G.704, G.823

Using the formulas mentioned above, FO link budget can be calculated. And the result is shown in Table 4.

Table 4. Link budget calculation

FO attenuation	16 km x 0,4 dB/km = -6,4dB
Fusion Spliceloss	4 x 0,1 dB = -0,4 dB
Connector loss	2 x 0.75 dB = -1,5 dB
Loss Margin	-5 dB
Total FO loss	-13,4 dB

Based on specification of transmitter light output power of laser diode, receiver sensitivity of photo diode for various distance is shown in Table 5.

Table 5. Typical light output power and receiver sensitivity based on distance

Distance	Output power	Receiver sensitivity
far	0 dBm	34 dBm
medium	-5 dBm	34 dBm
short	-8 dBm	34 dBm

To determine the option for suitable transmitting power is by adding power into FO loss calculation as shown in Table 6.

Table 6. FO loss and budget loss calculation

Distance	Output power	FO loss	Budget loss
far	0 dBm	-13,4 dB	13,4 dB
medium	-5 dBm	-13,4 dB	18,4 dB
short	-8 dBm	-13,4 dB	21,4 dB

Then to compare this result with specification of receiver sensitivity, is shown in table 7

Table 7. Comparison result between budget loss and difference

Distance	Receiver sensitivity	Budget loss	Difference
far	-34 dBm	13,4 dB	20,6 dB
medium	-34 dBm	18,4 dB	15,6 dB
short	-34 dBm	21,4 dB	12,6 dB

Based on calculation result as shown in Table 7, it conclude that option with transmit power for short reach is taken. Because the option is sufficient enough to operate an optical communication system. So this shows that specification of SDH equipment used for this design is a good choice.

2.4 Terrestrial Trunked Radio (TETRA) network

Voice communication via radio channel is also one of the services provided in telecommunication facilities. Radio communication is used for train dispatching. Digital based radio technology used for radio network is Terrestrial Trunked Radio (TETRA). Technical specification of TETRA is shown in Table 8.

Table 8. Technical specification of TETRA

No	Specification	Value	ETSI standard
1	Frequency Band	350 – 390 MHz	EN 303-035
2	Maximum output power	25 Watt (power class 2)	EN 303-035
3	RF performance	Conform with TETRAStandard	EN 300-392.2
4	Power consume	Input Power 115/230 V AC, 50/60 Hz	
5	Rx Sensitivity	Static 4% BER: - 119.5 dBm typical, -117.5 dBm guaranteed Typical Dynamic 4% BER: - 113 dBm typical, -111 dBm guaranteed	
6	Operating AmbientTemperature	- 30 to 55^{o} C	
7	Diversity Reception	Dual diversity	
8	Carrier Spacing	25 KHz	
9	GPS–simultaneous Satellites:	12	

The TETRA network runs under Ethernet platform supported by Asynchronous Transfer Modul (ATM). that use asynchronous time-division multiplexing. ATM is mapped to the three lowest layers of theISO-OSI reference model: network layer, data link layer, and physical layer. ATM is a core protocol used over the SONET/SDH backbone of the public switched telephone network (PSTN) and Integrated Services Digital Network (ISDN).

III. Result and analysis

Results of the research wereexplained as follows:

3.1 Optical communication system

As already described above that optical communication network or optical fiber network basically consist of ring SDH network using fiber optic (FO) link as transmission medium and PDH multiplexer network for user's access. SDH equipment is used as a large digital signal transport and also have function as Add Drop Multiplexers (ADM). An add-drop multiplexer is an important element of an optical fiber network. Amultiplexer combines, or multiplexes, several lower-bandwidth streams of data into a single beam of light. An add-drop multiplexer also has the capability to add one or more lower-bandwidth signals to an existing high-bandwidth data stream, and at the same time can extract or drop other low-bandwidth signals, removing them from the stream and redirecting them to some other network path. This signal is called tributary signal with data rate of 2 Mbps and also called as E1 fraction signal. This E1 signal is then broken down again into channel wise signals with basic rate of 64 Kbps. So the PDH and SDH networks deployed may be accessed by end users via various type of channel interfaces such as V.24, V.35, G.703 codir, 4W EM signaling for many application like voice communications, video, data transmission, Tetra and communication of PBXs as shown in Figure 2.

3.2 TETRA Network

TETRA uses Time Division Multiple Access (TDMA) with four user channels on one radio carrier and 25 kHz spacing between carriers. Both point-to-point andpoint-to-multipoint transfer can be used. Digital data transmission is also included in the standard though at a low data rate as shown in Figure 3.

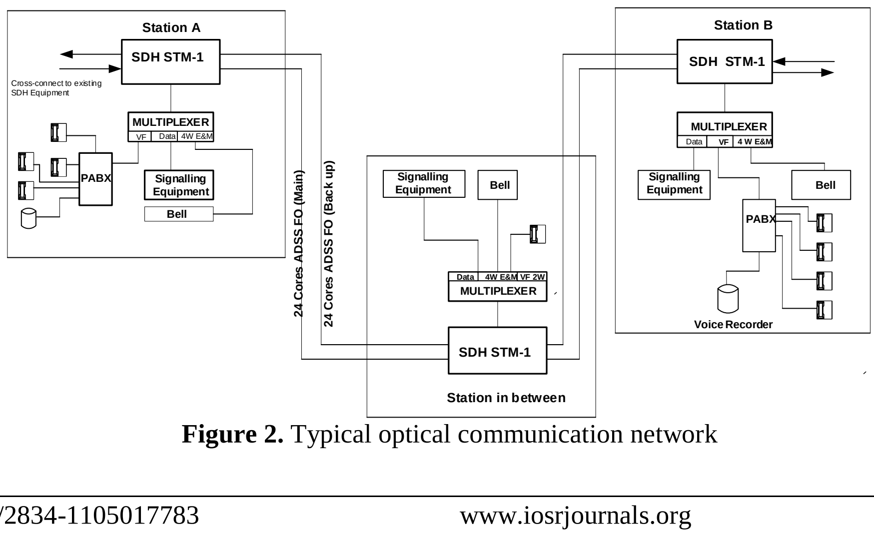

Figure 2. Typical optical communication network

TETRA Mobile Stations (MS) can communicate direct-mode operation (DMO) or using trunked-mode operation (TMO) using switching and management infrastructure made of TETRA base stations (TBS). As well as allowing direct communications in situations where network coverage is not available, DMO also includes the possibility of using a sequence of one or more TETRA terminals as relays. This functionality is called DMO gateway (from DMO to TMO) or DMO repeater (from DMO to DMO). In emergency situations this feature allows direct communications underground or in areas of bad coverage.

In addition to voice and dispatch services, the TETRA system supports several types of data communication. Status messages and short data services (SDS) are provided over the system's main control channel, while packet-switched data or circuit-switched data communication uses specifically assigned channels.

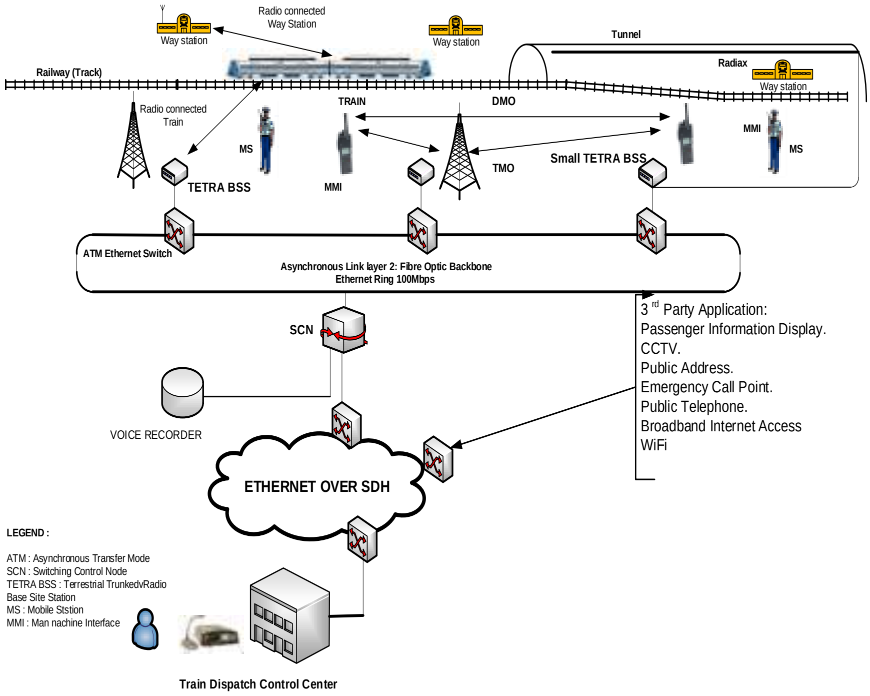

Figure 3. Architecture of TETRA network for train dispatching system

3.3 Bit Error Rate (BER) test

BER test and error performance was conducted only for2Mbps tributary signals. 2Mbps tributary signal specification is shown below.BER test result were shown in Table 9.

Interface : G.703
Line Code : HDB3
Framing : PCM30
Line rate : 2048 kbps

Table 9. BER test result

Nomor Tributary	Line Rate	Code Error Ratio	Bit Rate	Bit Error Ratio	Code Error	Total Bit	Bit Error
1	2047969	0,00E+00	63999	0,00E+00	0	3.840e 7	0
2	2047977	0,00E+00	63999	0,00E+00	0	3.827E 7	0
3	2047988	0,00E+00	63999	0,00E+00	0	3.840e 7	0
4	2047728	0,00E+00	63991	0,00E+00	0	3.839e 7	0

3.3 Error Performance measurement

Error performance was also conducted for tributary signals based on Rec ITU G.821.
The Measurement result was shown in Table 10

Table 10 Shows Error performance measurement result

Nomor Tributary	Errored Free Seconds	Error Seconds	Sev Error Secs	Available Time	Unavailable Time
1	600 100%	PASS 0 0%	PASS	600 100 %	0 0%
2	598 99.6667%	PASS 2 0.333%	PASS	601 100 %	0 0%
3	600 100 %	PASS 0 0 %	PASS	600 100 %	0 0%
4	592 98.6667%	PASS 8 1.333%	PASS	600 100%	0 0%

IV. Conclusion

Telecommunication facility for railway has already been designed, implemented and tested in small scale test bed. The test and measurement showed very good result. To demonstrate better performance of TETRA network it should be tested in real life environment.

Acknowledgment

I would like to express my gratitude to Indonesian Ministry of Research, technology and higher education who has funded this research. Hopefully this research can be beneficial to students, lecturers, researchers and especially railway operators.

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