Wide area radio network for the Telescope Array experiment

T. Nonaka*, R. Cady† , K. Honda‡, S. Iwamoto‡, J.N. Matthews†, and T. Tomida‡

for the Telescope Array collaboration

*Institute for Cosmic Ray Research University of Tokyo: 5-1-5 Kashiwanoha Kashiwa Chiba JAPAN
†University of Utah - High Energy Astrophysics Institute 115 S 1400 E 201, Salt Lake City, UT 84112-0830 USA
‡University of Yamanashi: 4-3-11 Takeda Kofu-shi,Yamanashi 400-8511 JAPAN

***Abstract*. The Telescope Array(TA) experiment, located in the western desert of Utah,USA,at** 39.3° **north and** 112.9° **west,is designed for observation of air shower from extremely high energy cosmic rays. The experiment has a surface Detector array surrounded by three Fluorescence Detectors (FD) to enable simultaneous detections of shower particles at ground level and fluorescence light along shower track. Since the experiment requires large acceptance, each facility is at a remote site. For the experiment,a long distance radio network system was developed at the TA site. This system consists of three communication towers and five sites of observation. Those are connected by 2.4 GHz and 5.7 GHz wireless LAN modules powered by solar panels and batteries. the detailed configuration , performance and stability will be presented.**

***Keywords*: Extensive Air Shower ,Ultra high energy cosmic rays, Data acquisition**

I. Introduction

There exists two major method of observation for detecting EHECRs. One is the method which were taken at the High Resolution Fly's Eye (HiRes) experiment that detects air fluorescence light along air shower track using fluorescence detector(FD). Another is that taken at the AGASA experiment that detects air shower particles at ground level using surface detectors(SD) deployed in wide area($\gtrsim 100km^2$).
The energy spectrum reported from the AGASA experiment [3] shows that there are 11 events beyond the GZK cut off [1], [2] . However the High Resolution Fly's Eye (HiRes) experiment report the existence of the GZK cut off [4]. The Pierre Auger experiment report suppression on the cosmic ray flux at energy above 4×10^{19}eV [5]. Since the experiments needs to be located far from town light and have large volume of detection. All instruments are operated at locations where commercial power and network are not available. So,constructing a stable long distance network is very important at the experiment.

II. Radio Network at Telescope Array Experiment

Telescope Array(TA) experiment was designed to have both fluorescence detectors (FD) and surface detector(SD) array using plastic scintillator. Those detectors have been deployed in desert of western Utah,USA (N39.3^o,W112.9^o,1500m asl). At this moment,three Fluorescence telescopes and 507 surface detectors have been constructed and deployed. Each SD is deployed at 1.2km intervals. Fig.1 shows area of deployed surface detectors and position of air fluorescence detectors. The details of SD array and DAQ can be found in paper

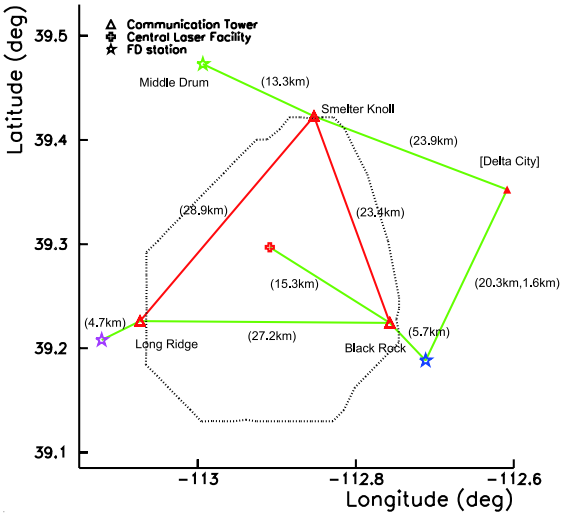

Fig. 1. Area of completed 507 SD array surrounded by 3 FD stations($\star$). The $\triangle$ represents communication tower where the trigger judgment electronics for sub-array are installed. Lines drawn to connect each tower and facilities represents the links between antennas.

Fig. 2. One of the communication tower located at a hill called Smelter Knoll(SK). Three stands with four solar panels are seen.

[9], [10]. For the fluorescence detectors can be found a paper[6]. The point displayed with △ in Fig.1 represents location of communication tower. Fig. 2 shows one of the communication tower located at a hill called Smelter Knoll(SK) near the north edge of SD array. Other two towers are located at hills near west and east edge of SD array called Black Rock Mesa(BR) and Long Ridge(LR). Communication towers have a role of collecting trigger information from SDs and providing general purpose of access to the FD stations and Central Laser Facility(CLF)[7]. Data collected from SD are temporary stored at communication tower and regularly transfered to Delta city which is closest town from observation site through this network system.
Table I shows distance and radio settings of each line. There are two range of frequency.One is 5.7 GHz and another is 2.4GHz range. The line between SK - BC R tower and SK - LR tower is for data acquisition of SD. No general purpose of access to FD stations and CLF does not interfere data acquisition line. About the SD trigger information which is transmitted through the line can be found in a paper [10].

TABLE I
LIST OF INSTALLED RADIO NETWORK

Line	distance	Radio frequency
SK - BR tower	23.4 km	5.735 GHz
SK - LR tower	28.9 km	5.840 GHz
Delta - SK tower	23.9 km	5.800 GHz
SK - MD FD	13.4 km	2.4375 GHz
Delta - BRFD[1]	20.3 km(+1.6 km)	5.790(,5.755) GHz
BRFD - BR tower	5.7 km	5.820 GHz
BR - LR tower	27.2 km	5.775 GHz
BR tower - CLF	15.3 km	2.4550 GHz
LRFD - LR tower	4.7 km	5.735 GHz

III. COMMUNICATION TOWER

TABLE II
LIST OF MODULES AT TOWER AND POWER CONSUMPTION

LR tower	
DAQ PC	5 W
Tower monitor PC	5 W
Router/Hub (×2)	5.6 W (×2)
Radio antenna (×3)	10.3 W (×3)
SD electronics	4.2 W
(total)	56 W
SK tower	
DAQ PC	5 W
Tower monitor PC	5 W
Router/Hub (×3)	5.6 W (×3)
Radio antenna (×4)	10.3 W (×4)
SD electronics	4.2 W
(total)	72 W
BR tower	
DAQ PC	5 W
Tower monitor PC	5 W
Router/Hub (×2)	5.6 W (×2)
Radio antenna (×4)	10.3 W (×4)
SD electronics	4.2 W
Amplifier for mobile radio	18.8 W
(total)	85 W

[1]There is a relay point at inside of Delta city

Fig. 3. A long distance radio antenna working at Telescope Array

Fig 2 shows a communication tower placed at Smelter Knoll. Three stand with four solar panels (KC125J Kyocera make) are seen. Control electronics for SD data taking is equipped at the top or the tower. Parabolic antennas for long distance link can be seen at top of tower and on the solar panel stand. Some of radio antennas are mounted on the top of solar panel stand because radio antennas interfere each other when radio frequencies are close and distance between antennas are not enough. Power consumptions by each components are summarized in TableII Including instruments operated for SD. There,the power consumption is calculated with considering of power Fig.3 shows an antenna which is working at Delta city to communicate with TA site. dissipation at DC-DC converter as 20%.

A. Battery system of Communication tower

Communication work is powered by solar panels and batteries (DCS100lT C&Gtechnologies make). The charging for the battery are controlled by charge controller (SunSaver-20L (SS-20L) Morningstar make). One charge controller is equipped for two solar panels and three batteries. The unit can provide 16W of power constantly under the solar radiation at observation site. There the safety factor is greater than 1.5.
Each solar panel stand consists of two of this unit. Two solar panel stand are installed for all tower. Output of the charge controllers are convined and distributed to instruments. Additional two unit are installed at BR tower to supply power for the amplifier for the mobile radio and long distance radio antenna to CLF site. At SK tower , the additional two unit are installed to supply long distance radio antenna to Middle Drum FD station. A monitoring system also installed to understand the condition of power [11]. There battery voltage and charging current are monitored. Fig.4 is an example of monitoring data of a unit installed at LR tower. For more than one year, there was no power failure at current battery system on the tower.

IV. RUNNING STATUS AND SUMMARY

Currently the network are operated with 3 Mbps of through put. It is sufficient for SD data acquisitions ,

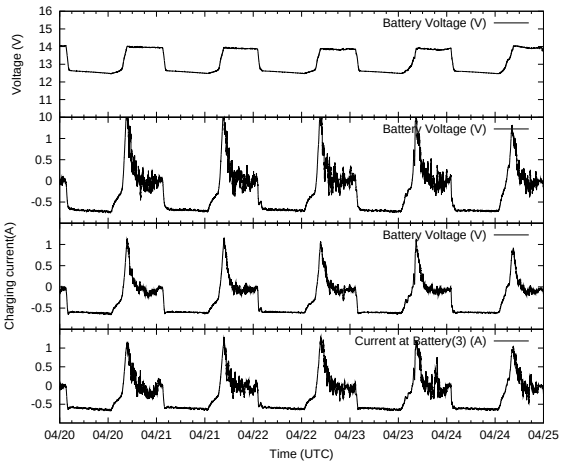

Fig. 4. The example of tower monitor data. Variation of 10 min average of battery voltage and current at battery terminals are plotted along the UTC. It is seen that batteries are charged up to full charge in daytime and discharging in night time.

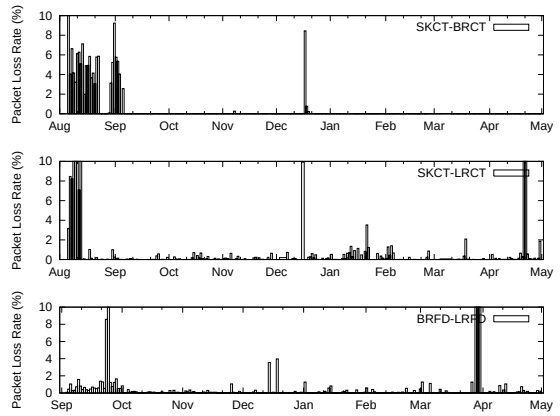

Fig. 5. Long term stability of the network from Aug.2008. Top two panels shows daily packet loss rate at the line of SK to BR tower and SK to LR tower used for SD data acquisition. Bottom panel shows the one at the line of BR FD station to LR FD station.

data transfer and operation of FD stations. The network are maintained by monitoring the packet loss rate. Fig.5 shows daily average of packet loss rate at the lines those are monitored at current system. Up to October. 2008 there is a period were shows higher loss rate caused by interference among radio modules. After adjusting the radio frequencies and distances between antennas, network shows good stability except some periods of major maintenances occurred at 17,18.Dec.08 (maintenances for SD data acquisition PC) and end of Mar.09 (misalignment and damage due to a strong wind.)

V. Acknowledgement

The Telescope Array experiment is supported by the Ministry of Education, Culture, Sports, Science and Technology-Japan through Kakenhi grants on priority area (431) “Highest Energy Cosmic Rays”, basic researches 18204020(A), 18403004(B) and 20340057(B); by the U.S. National Science Foundation awards PHY-0601915, PHY0703893, PHY-0758342, and PHY-0848320 (Utah) and PHY-0305516 (Rutgers); by the Korean Science and Engineering Foundation (KOSEF, Grant No. R01-2007-000-21088-0); by the Russian Academy of Sciences, RFBR grants 07-02-00820a and 09-07-00388a (INR), the FNRS contract 1.5.335.08, IISN and Belgian Science Policy under IUAP VI/11 (ULB). The foundations of Dr. Ezekiel R. and Edna Wattis Dumke,Willard L. Eccles and the George S. and Dolores Dore Eccles all helped with generous donations. The State of Utah supported the project through its Economic Development Board, and the University of Utah through the Office of the Vice President for Research. The experimental site became available through the cooperation of the Utah School and Institutional Trust Lands Administration (SITLA), U.S. Bureau of Land Management and the U.S. Air Force. We also wish to thank the people and the officials of Millard County, Utah, for their steadfast and warm support. We gratefully acknowledge the contributions from the technical staffs of our home institutions.

References

[1] K. Greisen, *Phys. Rev. Lett. 16, 748,(1966)*
[2] T. Zatsepin and V.A.Kuzmin, *JETP Lett 4 78,(1966)*
[3] M. Takeda et.al., *Phys. Rev. Lett. 81, 1163,(1998)*
[4] T. Abu-Zayyad et.al, *Phys. Rev. Lett. 92, 151101,(2004)*
[5] J. Abraham et.al,*Phys.Rev.Lett.101:061101,(2008)*
[6] H. Tokuno et.al *Proceedings of the 31th ICRC Łódź ID=942,(2009)*
[7] S. Udo et.al,*Proceedings of the 30th ICRC in Merida 5:1021,(2007)*
[8] T. Nonaka et.al *Proceedings of the 30th ICRC in Merida,5:1005,(2007)*
[9] T. Nonaka et.al *Proceedings of the 31th ICRC Łódź ID974,(2009)*
[10] A. Taketa et.al *Proceedings of the 31th ICRC in Łódź ID ???,(2009)*
[11] S. Iwamoto et.al *University of Yamanashi Master thesis ,(2009)*