BeagleBone Black Powered Data Concentrator for Connected Devices

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ABSTRACT

The main task of Data Concentrators is to collect data which is originated from any devices in the network that is connected via wired or wireless interfaces and protocols such as RS232C/RS485 with Modbus, USB, Ethernet, Wi-Fi, GSM/GPRS, Zigbee etc. Then they process the obtained data and, in a subsequent communication, transmit the acquired data to the Head-End Server System. This paper presents our work of employing the BeagleBone Black (BBB) board as a data concentrator for connected sensor devices. In the last few years, there has been a rapid increase towards single-board microcontrollers. These days, trend has shifted towards development of full-fledged credit-card sized computer's like Arduino Mega2560, Raspberry Pi, Orange Pi, Chip and even Beaglebone Boards. These boards are low cost, low power, easy deployable and has user-friendly configurable options. The BeagleBone Black (BBB) board is a low cost, open hardware and expandable computer launched by a community of developers sponsored by Texas Instruments. This board is showing tremendous increase in adaptability and implementation in diverse areas like Robotics, Drones, Smart Homes, IoT devices, Linux and Cloud Computing Servers and even more.

Keyword: - *Data Concentrators , BeagleBone Black (BBB) board , DCCD, IoT, Open Source Hardware, etc.*

1. INTRODUCTION

According to a recent Annual Energy Outlook, worldwide energy consumption will increase 50 percent by 2035, and electricity alone will increase by 30 percent during the same time1. Global demand for electrical power has outstripped supply and there's no end to the situation in sight. Unfortunately, only generating more power is not a viable solution. A more feasible way for both the short and long term is to be more efficient with the electrical power that is already being generated and distributed over the grid.

A step in this direction would be to make the grid itself more intelligent so that power utilities, governmental regulators, power distribution companies and consumers could better monitor, analyze and control energy generation, distribution and usage. Along with smart meters deployed worldwide in the last ten years, data concentrators play a key role in enabling intelligent power consumption with more robust end-to-end communications.

In the evolution of modern telecommunications systems there was a requirement to connect large numbers of low-speed access devices with large telephone company 'central office' switches over common paths. During the first generations of digital networks, analog signals were digitized on line cards attached to the telephone exchange switches. In an effort to reduce local loop costs, it was decided to push this conversion closer to the customer premises by deploying small conversion devices in customer neighborhoods. These devices would combine multiple digital signals on a single link to a larger telephone switch, which would provide service to the customer. These devices were initially called Data Concentrator.

The Elettra Sincrotrone Trieste research centre manages two light sources: Elettra, a 2.4 GeV third generation synchrotron, and FERMI, a 1.5 GeV seeded Free Electron Laser (FEL) based on a linear accelerator. The large

number of subsystems that make it possible to generate and deliver the photon beams to the users, require an up-to-date distributed control system technology. The ever growing capabilities of modern micro-controllers, together with the cost reduction induced by the competition between manufacturers, make a number of small, flexible and powerful Systems On Board (SOB) commercially available at low cost. Available with a wide range of clock frequencies and I/O capabilities, SOBs can be effectively used in a particle accelerator control systems as a customizable embedded platform. With these considerations in mind, a survey has been carried out to find the most suitable SOB to be used as the core for a general purpose embedded platform, or "smart node"; the BeagleBone Black has been eventually selected.

The data may originated from any devices in the network that is connected via wired or wireless interfaces and protocols such as RS232C/RS485 with Modbus, USB, Ethernet, Wi-fi, GSM/GPRS, Zigbee among others. The data is stored in servers in the network where the data is processed to generate information. Network clients such as desktop computers, laptops, smartphones, tablets can access this information for smart business decisions. The information may be displayed on annunciators and shared across locations through the gateway.

2. DATA CONCENTRATORS

Data concentrators in substations provide a vital interface with intelligent electronic devices (IEDs). Retrieving operational and non-operational IED data and communicating it to the corporate network, they provide users with the data required for faster, more informed business decisions. A data concentrator is the core of data and energy management in an advanced metering infrastructure (AMI). It provides the technology to measure and collect energy usage data. The concentrator can also be programmed to analyze and communicate this information to the central utility database. Not only can the utility providers could use this information for billing services, but can improve customer relationships through enhanced consumer services such as real-time energy analysis and communication of usage information. Additional benefits of fault detection and initial diagnosis can also be achieved, further optimizing the operational cost. Data concentrators also called data aggregators provide the core functionality required to measure, analyze and collect the data. They then communicate that data to a central database for troubleshooting and analyzing.

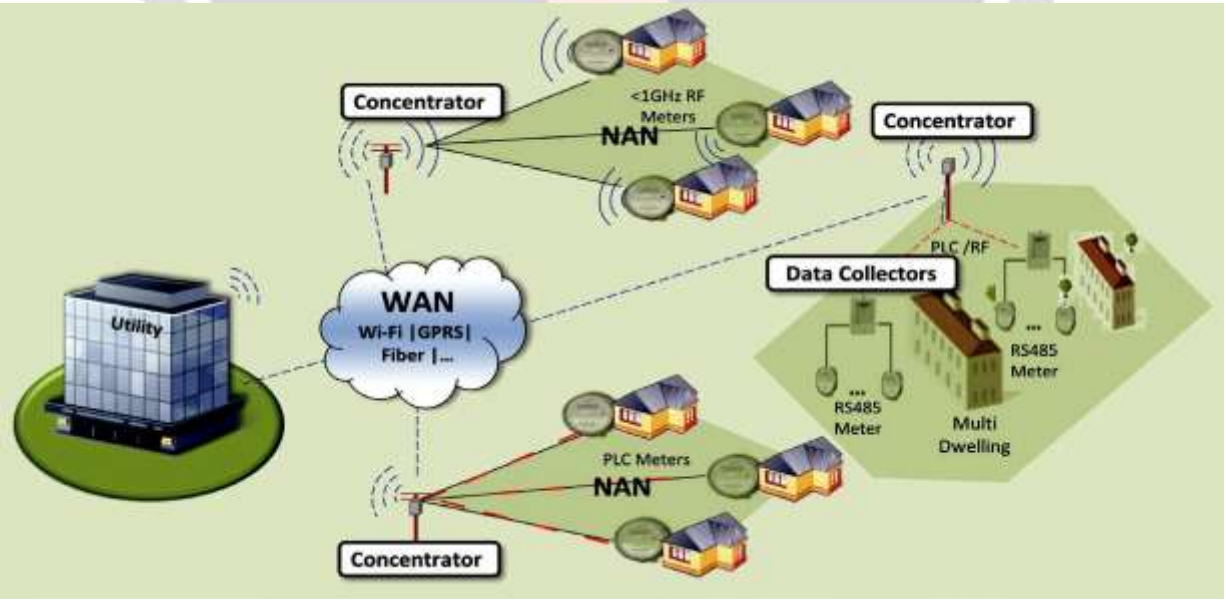

Figure 1: Typical Data Concentrator Network

2.1 Main Functions of a Data Concentrator

Data concentrators push intelligence to the edge of the grid by integrating, organizing and aggregating information from e-meters or other end equipment on the grid. Typically located at the transformer or a secondary substation level, data concentrators need to have the following basic functionS:

- Provide reliable communication with meters and head ends
- Secure consumers' data and information
- Monitor regional grid status
- Support various data management applications.

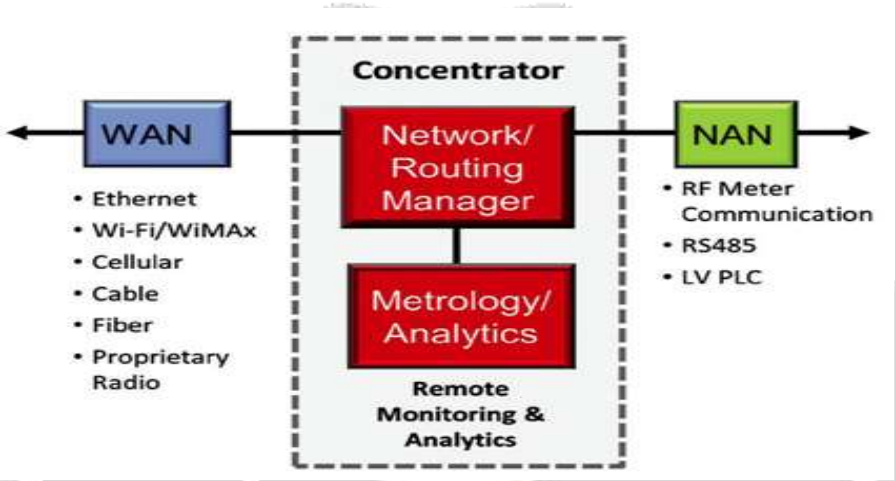

Figure 2: Data concentrator functional block diagram

2.2 Types of Networks connected to Data Concentrators for Communication

Basically there are two types of networks connecting to data concentrators:

a. NAN: Neighborhood Area Network and
b. WAN: Wide Area Network

2.2.1 NAN Communication

Power line communication (PLC) has been used for many decades and gained worldwide interest with its ability to modulate communication signals over existing power lines and enabling devices to be networked without introducing any new wires or cables. This capability is extremely attractive across a diverse range of applications; including utility metering, home area networks, lighting and solar, which can leverage greater intelligence and efficiency through networking. A variety of new services and applications now require greater reliability and data rates than PLC techniques from the past. Several factors impact PLC performance, including impulsive and narrowband noise, time-varying line impedance and frequency-selective channels.

2.2.2 WAN Communication

10/100/1000M Ethernet and optical cable have been widely used in grid infrastructure as WAN options, but those may be not accessible everywhere, nor the best options from a CAPEX/OPEX perspective. Wireless access technology is another choice. Currently, GSM/GPRS technology has been adopted (up to 52kbps throughput); future alternatives are WCDMA/CDMA2000 (up to 2Mbps) and LTE (up to 1Gbps). The appropriate choice for WAN technology will likely be made on the following criteria: availability, price, throughput, latency and indoor coverage, with a mix of different technologies possible in the future.

3. OVERVIEW OF BEAGLEBONE BOARD

Beagleboard was originally developed and introduced by Texas instruments in year 2008 by using OMAP3530 System-on-a-chip technology with basic objective done by a small team of engineers to come out with some sort of educational board that can provide good platform to various educational and research centres/institutions across the world to teach/research/develop open source hardware based projects. Beaglebone is regarded as Giant step from Microcontrollers such as AVR, PIC, ARM Cortex M3, 8051*etc*. to full-fledged microcomputer. Beaglebone is regarded as fully functional computer like desktop or laptop.

OMAP3530 is integrated with ARM Cortex-A8 CPU, a TMS320C64x+ DSP for video acceleration and encoding and decoding audio and also supporting 2D and 3D rendering using OpenGL ES 2.0.

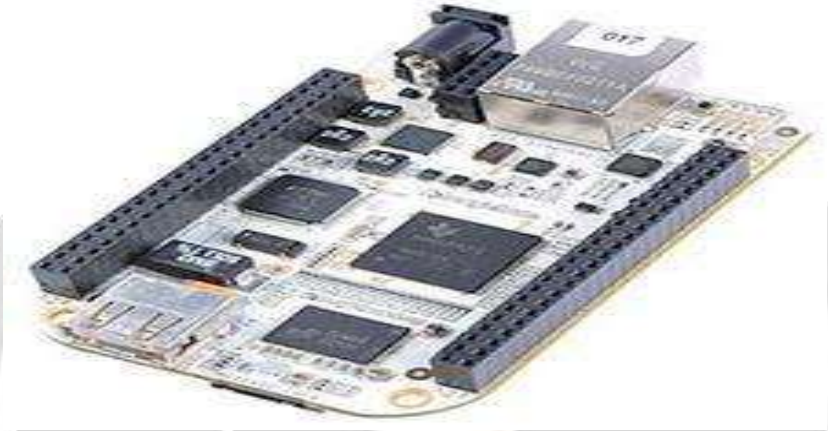

Figure 3: Beaglebone board

3.1 Technical Specifications & Features of Beaglebone

The following are the Technical Specifications of Beaglebone:

- Processor- OMAP3530 SoC- 720 MHz ARM Cortex-A8 core
- TMS320C64+- 520 MHz HD Capable Processor supporting Video Playback of 720p@30fps
- 256 MB LPDDR RAM
- 256 MB NAND Flash Memory
- Slots- 1 USB Port, 1 USB OTG, SD/MMC Port, 3.5mm Jack, JTAG Connector, Power Socket 5V, S-Video, DVI-D, RS-232, Ethernet Interface.
- Operating Systems Supported- Android, Linux (Fedora, Angstrom, Ubuntu, Gentoo, Arch, Maemo), VxWorks, FreeBSD, Windows CE, Symbian QNX & RISC OS 5.

The following are the Features of Beaglebone:

- Low-Power Credit Card Small Size compact ergonomics.
- Large number of GPIO I/O Pins. High Performance Computing experience.
- Supports deterministic execution hardware via dedicated processing unit.
- Robust and Wide options for connectivity.
- Open Source Hardware technology- Giving Options to manufactures to integrate ARM Technology for developing cloned Beaglebone development boards.
- Open Source Software Technology- Giving Options to install wide range of Android and Linux flavoured operating systems.
- Support via large and continuous expanding community of developers, users and researchers.
- Supports interfacing with wide range of Analog cum Digital Sensors in turn opening doors for various IoT and Cloud based projects.

3.2 Why Beaglebone?

Beaglebone, a powerful ARM Technology based development board is widely adopted by researchers and embedded systems enthusiasts all over the world because of the following reasons :

- Networking Capabilities: Beaglebone has on-board 10/100 Ethernet port. Apart from peer to peer network connectivity, it is capable for providing all sorts of networking services like FTP, TELNET, SSH and even has capability to act as web server to publish website using lighttpd web server package.

- Remote Control: As, Beaglebone has efficient networking capabilities, it also facilitates Remote Control access. In some situations, it is necessary to control Beaglebone remotely. With use of VNC/MobaXterm based software, entire graphical desktop can be viewed and edited remotely without any hiccup.

- Filesystem: As compared to Windows, Embedded Linux file systems have much enhanced security, organization and retrieval capabilities. Linux file system is known on ext3/ext4 which is pure file based system providing much better capabilities towards managing and organizing system functions/system calls as compared to FAT32/NTFS file systems.

- Time Management: Beaglebone board is equipped with NTP (Network Time Protocol) which enables accurate time synchronization via Internet time servers.

- Wide range of Programming Languages: Beaglebone has capability to support various compilers, tools and editors to facilitate users to write programming code of various programming languages like C, C++, Java, Python, Perl, Ruby, Shell Scripting, Ruby on Rails and even latest programming languages like R, Hack from Facebook is also supported.

- Supports Multitasking: As Beaglebone runs Linux operating system which has capability to run multiple-processes in terms of programs and tasks at single point of time. Beaglebone provides users with Multi-tasking capability in terms of multi-processes without hindering its performance.

- Growing Support Worldwide: As now Beaglebone has plenty of users, research groups cum institutions and Hobbyists working on several multi-platform projects, any person using Beaglebone can take help from online forums, developer communities and even manufactures are providing customer support 24x7 which in-turns makes it widely adoptable platform across other development platforms.

3.3 BEAGLEBONE BLACK:

BBB is the newest product in the Beagle family. This board features a powerful TI Sitara™ ARM Cortex™-A8 processor which runs at 1 GHz. And a 2 GB on-board flash memory acts as the “hard drive” for the board to host a Linux operating system and other software development tools. With a user-friendly, browser-based Bonescript programming environment called Cloud9, a learner can easily program the BBB board to rapidly prototype electronic systems that interface with real-world applications. As the knowledge of users develops, the board provides more complicated interfaces including C/C++ functions to access digital and analog pins aboard the ARM Cortex A8 microprocessor. The full power and capability of the BBB board can be programmed in the underlying onboard Linux operating system, such as Angstrom or Ubuntu. Beaglebone Black is currently most widely sold board worldwide because of its low-cost. Beaglebone black is regarded as most utilized Beaglebone board amongst all boards available till date for various applications and hardware based projects and has support of developers and hobbyists communities worldwide. It is powered by AM335x 1GHz ARM Cortex A8 processor and supports 3D graphics acceleration. Because of its configuration this board can boot Linux in less than 10 seconds.

Applications: Robotics, Solar Technology, Full-Fledged Portable PC, Spider Bot, Camera Drones.

Table -1 Technical Specification of Beaglebone Black

SoC	CPU	GPU	DSP	RAM	Connectivity Options(Audi o/ Video)	Storage/ Network Option	Internal Modules	Software	Price
AM3358/9	ARM-Cortex A8	Power VR SGX 530	N/A	512	1 USB, Micro-HDMI, cape add-ons	Ethernet	UART, PWM, GPMC, MMC, SPI, I2C, ADC, CANbus, Timers, JTAG	Ubuntu, Android, Debian, Cloud 9, IDE on Node.js w/Bone script Library	$55

3.4 Beaglebone Black Board-Components

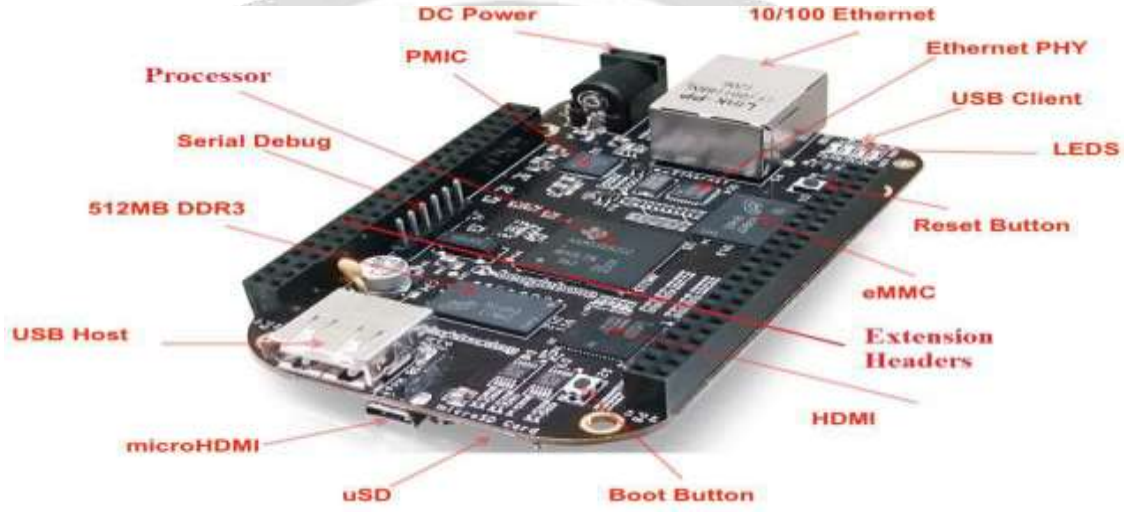

Figure 4: Beaglebone Black Board-Components [Img Src: www.beagleboard.org]

The following are the components of Beaglebone Board:

3.4.1 Processor: Processor being the heart of Beaglebone board manages all sorts of controls and operations. Beaglebone processor is based on ARM Cortex A8/A15 Processor technology running at various clock speeds like 720 MHz, 1GHz, and 1.5GHz.

3.4.2 RAM: Depending on various generation models, Beaglebone boards are equipped with 128/256/512/2048 MB RAM.

3.4.3 DC Power Jack: Beaglebone requires 5V and 500 mA of DC power to operate. Along with DC power jack, 2.1 mm barrel jack connector will be required to power the board. Beaglebone facilitates over voltage protection chip upto 12V.

3.4.4 Ethernet Port: Beaglebone has on-board 10/100 standard RJ45 Ethernet Port supporting all sorts of networking protocols along with Wi-Fi connection sharing.

3.4.5 Reset Button: Reset Button reboots the board. It provides logic 1 or 0 to trigger the processor. Functioning similarly like Reset Button on computer/smartphones, it reboots the entire operating system and also provides backup from failure if lock up situation occurs.

3.4.6 USB Host: USB Host provides same features like USB port on normal computers/laptops. Beaglebone USB host ports enables users to connect various 3rd party peripherals like Keyboard, Mouse, Web Camera, Wi-Fi adopters and external storage devices like pen drives, USB card readers and hard disk drives.

3.4.7 LEDs: Beaglebone board has LED located aside power connector to indicate power ON signal when power applied to board. Most of the boards are equipped with 4 LED's with following functionalities: LED0 will be ON when Board is up and running. LED 1 will indicates microSD card operations. LED 2 indicates Active CPU active situation. LED 3 indicates flash memory access.

3.4.8 Extension Headers: Beaglebone has 2 extension headers on left and right side which facilitates integration of various electronic components like LED's, Switch's, Sensors, and Modules *etc*. for developing various projects.

3.4.9 USB Client: USB Client port is basically used for connecting Beaglebone to computer and power would be provided via USB. When connected to computer, it appears like storage device.

3.4.10 MicroSD Card Slot/uSD: MicroSD card slot facilitates integration of microSD cards to store operating systems, applications and data. Taking Beaglebone black into consideration, where operating system is stored on onboard flash memory by default, any updates can be done via sd card slot only. Operating systems can be downloaded on Beaglebone website which can be written on SD card via Win32Disk Imager software.

3.4.11 microHDMI: microHDMI port does the work of connecting Beaglebone board to HDMI enabled Monitor/TV. It supports maximum resolution of 1280x1024 pixels.

3.4.12 Serial Debug: Serial Debug is used for serial communications to connect an FTDI TTL-232 cable or breakout board and enable text based terminal via USB.

3.4.13 eMMC/Onboard Flash Memory: Beaglebone (Black version) has operating system stored on eMMC/onboard flash memory to boot up the board without any SD card requirement.

3.4.14 Boot Button: Available only in Beaglebone black. Continuous hold of Boot Button instructs Beaglebone to boot from SD card attached on SD card slot rather than onboard flash memory.

3.4.15 PMIC (Power Management Integrated Circuit): PMIC module provides power backup solution to Beaglebone via connecting li-po batteries. These batteries will act as UPS for Beagle bone for providing backup to users over electricity failure to shut down the board or does necessary important work till batteries last long.

4. METHODOLOGY

The data may originated from any devices in the network that is connected via wired or wireless interfaces and protocols such as RS232C/RS485 with Modbus, USB, Ethernet, Wi-Fi, GSM/GPRS, Zigbee. The data is stored in servers in the network where the data is processed to generate information. Network clients such as desktop computers, laptops, smartphones, and tablets can access this information for smart business decisions. The information may be displayed on annunciators and shared across locations through the gateway.

The BeagleBone is quite a powerful tool when it comes to data acquisition, because it provides easy access to the web and lots of GPIOs. To controlling an output, reading a button/sensor, controlling a motor are quite easy with BoneScript. Most functions of begalbone script is very similar to Arduino.

4.1 Specification of DCCD System

- Multi-protocol interface to Sensor Nodes
- Wired and Wireless TCP/IP connectivity to Server on Intranet or Internet
- Sensor Data fusion, Data Concentration and Data Publish
- Optional use of various software protocols such as Modbus, MQTT and other IoT protocols, TCP/IP protocols such as HTTP, FTP

5. BLOCK DIAGRAM OF THE SYSTEM

In our system Begalbone balck Board is used as data concentrator for connected devices. The BBB has some Desirable characteristics of an embedded platform for DCCD are:

- wide set of low level analog and digital I/O subsystem (e.g. GPIO, SPI, ADC, …);
- remote communication interfaces; · multiple communication protocol support;
- high level operating system support; · software and documentation availability;
- long term commercial availability and support;
- flexibility and modularity; · competitive purchasing and maintenance costs;
- deterministic (real-time) capabilities.

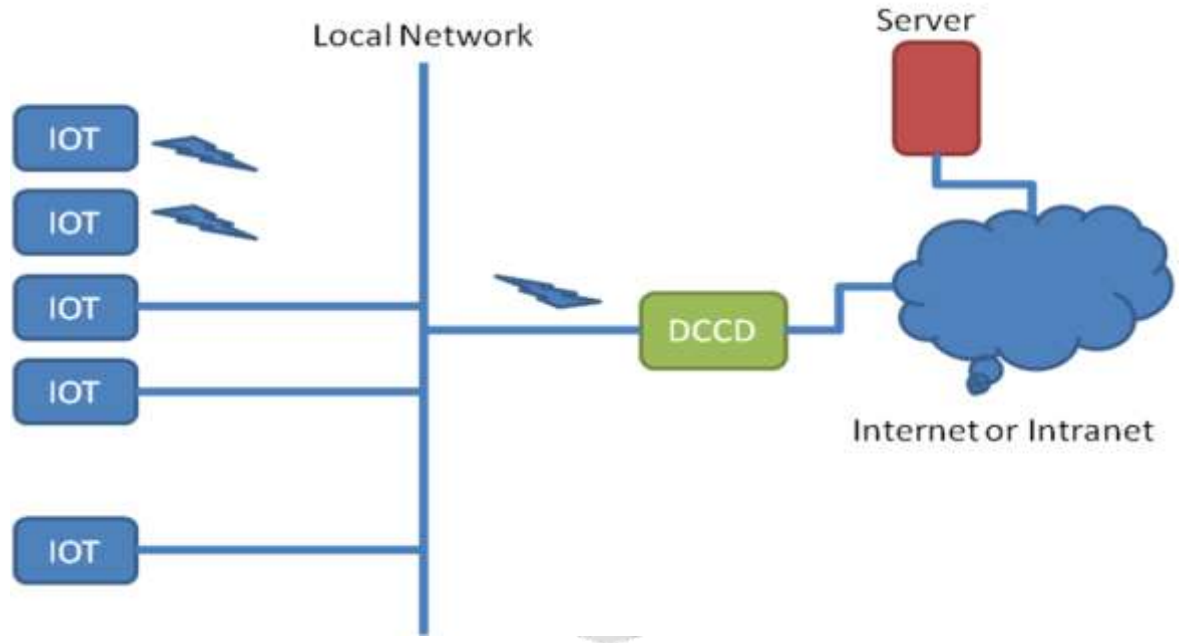

Figure 5: Block Diagram of Beaglebone Black Board based Data concentrators for connected Devices

The Data Concentrator for the Connected Devices is an embedded appliance that collects data from various embedded devices in a network, fuses the data as appropriate and transmits the same upstream to a server where the data is logged into a database for further analytics.The main work of DCCT is to collect data which is originated from any devices in the network that is connected via wired or wireless interfaces and protocols such as RS232C/RS485 with Modbus, USB, Ethernet, Wi-Fi, GSM/GPRS, Zigbee etc. . The data is stored in servers in the network where the data is processed to generate information. Network clients such as desktop computers, laptops, smartphones, tablets can access this information for smart business decisions. The information may be displayed on annunciators and shared across locations through the gateway.The BeagleBone Black (BBB) board works as a data concentrator for connected sensor devices.

Figure 6: Block Diagram of the architecture of DCCD

6. WORKING OF THE SYSTEM

The BeagleBone is quite a powerful tool when it comes to data acquisition, because it provides easy access to the web and lots of GPIOs. To controlling an output, reading a button/sensor, controlling a motor are quite easy with BoneScript. However, with thousands on devices generating data from sensors and transducers, it is not sufficient to collect the data and display in graph or numerical form. The sensor data needs to be combined to generated information as well as reduce the size. This can be achieved by devices that are located between the sensor devices and the storage/processing servers. These devices are called data concentrators. Examples of data concentrators can be found in metering networks where data is periodically collected from the meters and transmitted to the central servers for billing and other activities. The data concentrators can also act as control devices to enable/disable meters and other actions.

The data concentrator developed in this project is an embedded system that collects data from the sensor nodes and pushes to servers to storage and analysis. The data concentrator can be configured by host software with a user interface similar to the one shown in figure below.

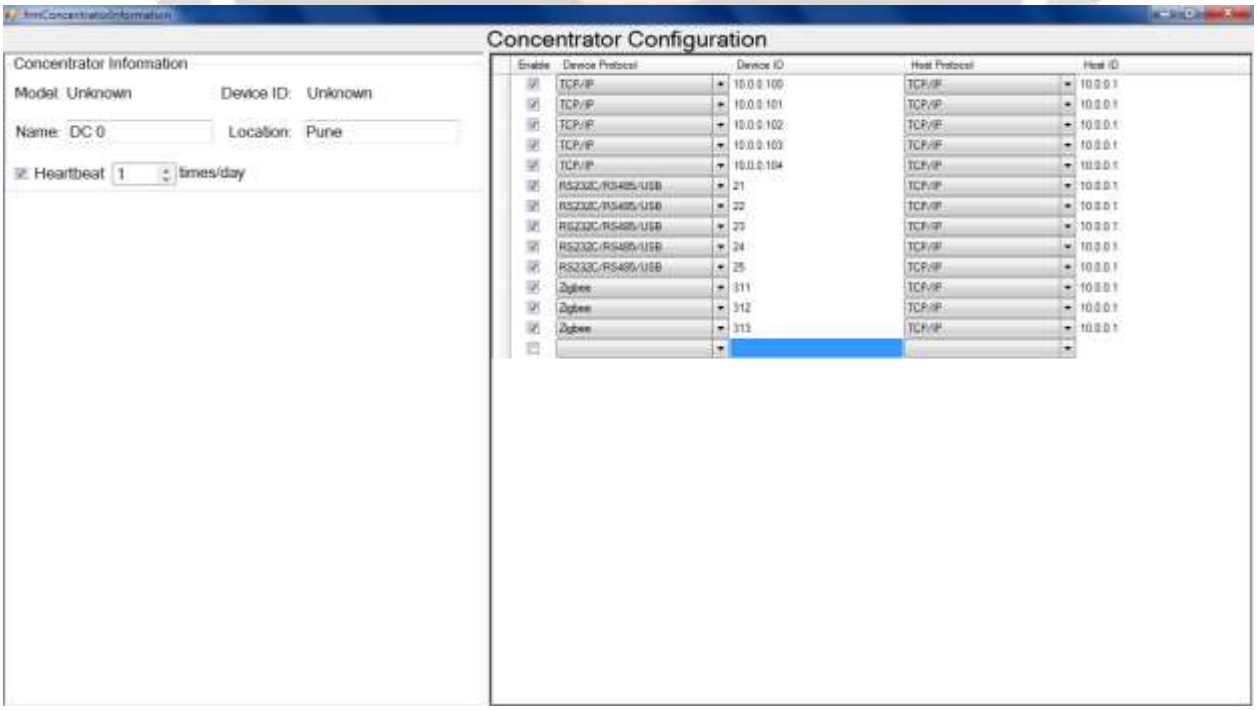

Figure 7: Data Concentrator result after configuration

The concentrator configurator initialises the concentrator device by setting the name and location of the device. The device can also be configured to send status messages called “Hearbeat” that indicate the health of the device as well as the current status of data movement.

The device can also be programmed to collect data from a device and send the same to a host. The protocol and ID of the device as well as the host can be programmed. Thus devices connected using TCP/IP (wired Ethernet or wireless Wi-Fi) can be identified by their hostname or TCP/IP address or devices connected using RS232C/RS485/USB/Zigbee can be identified by their using device address.

The host is typically, but not restricted to, a LAN or Internet based server with its own TCP/IP address or hostname. There may be multiple hosts in the network that can collect data from multiple devices or one device may send data to multiple servers. The matrix of data source and destination is downloaded to the concentrator device as a table which is used by the concentrator to route the data.

The concentrator pulls the data from the devices at a preset time, optionally pre-processes the same and forwards the pre-processed data to the host. This is repeated for all devices.

6.1 Processing Steps

a. Plug the USB cable of BBB into your computer having Linux OS.
b. Wait for the board to initialize.
c. The leds should have gone all solid and be blinking
d. Load BBB flash Linux image
e. Open terminal window.
f. type ssh root@192.168.7.2
g. It will prompt for a password but there isn’t one by default so just press enter
h. You should now be logged into the board home directory.
i. Connect BBB with Ethernet LAN.

Figure 8: Connection of Power and LAN to BBB

j. Login BBB using putty software
k. Run the server program
l. Connect client using IP address or communication port number
m. Then there will be duplex communication established between server and clients.

7. RESEARCH AREAS/FUTURE SCOPE FOR PROJECT DEVELOPMENT’S

Using different types of sensor devices we can collect different types of data, those data can further processed by data concentrator for various applications. Hence, research areas would be enlisted

in tabular form which will provide wide scope for researchers to research and develop wide range of products on various areas of technology.

Table -2 Research Areas & Project Outcomes/Products of Beaglebone Black Boards powered DCCD

Research Area	Possible Research Outcomes/Products Development/ Research and Development Projects
Robotics	2 Balances Robots, Master/Slave Robot, Hexapod Robot, Legged Robot, Prowlerbot, Lego Based Robots, Cape, BeagleBot, OpenROV
Smart Homes	Smart Home Management and Energy Monitoring, Pour Steady, Home Cleaning, Intelligent Systems, Debrew, Smart Home Security Management
Drones	Quadcopter, RC Planes, Octocopters, Bi- Copters, Surveillance Drones, Hex-copters
Network Security	Linux Based Encryption, Cryptography, Proxy Server, Linux Secured Server Deployments, Network Traffic Monitoring, Internet Server
Cloud Computing	Cloud Server, Cloud Security, Embedded Cloud Computing, Cloud based Hosting, Web Server, Cloud Computing Cluster Development, Virtualization, Cloud Load Balancing, Cloud Based Fault Tolerant Research
IoT	IoT Devices, Smart Gizmos, Kitchen Automation, Sensor Based communication technology, NFC, Smart Money Transfer Technology, IoT Development Kits
Sensors Integration	All types of Analog and Digital Sensors for wide applications in Homes, Military, Irrigation, Automation, Medical, Automobiles, Nuclear Power Plants, Smart Grids, and Intelligent Production Machines.
Solar Technology	Smart Solar Tracking System, Solar Generators *etc*.
Open Source Platforms/Applications	Linux Development, Programming (All Languages), openCV)

7. CONCLUSION

Data concentrators play an important role in a modern system design. To design cost-efficient and future-proof concentrators, developers need to carefully consider WAN and NAN options, hardware platform scalability, software availability, and networking/data security design.

Beaglebone being ARM based board provides efficient, smart, reliable and flexible platform to various professionals, researchers and embedded systems enthusiasts to take up this board for developing various live and ready to use market implementation projects. Beaglebone community is contributing a lot in research and is growing day by day. Beaglebone boards with improved configurations and connectivity options are launching at regular intervals in this area providing more project development options, high performance and making portable boards full-fledged Linux and cloud computing servers.

In this paper, various research areas which can be taken up by researchers is also being mentioned for providing them with varied options of research applications by using Begalbone Black (BBB) powered DCCD.

8. ACKNOWLEDGMENT

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