Electricity Theft Control with Real-time Billing Framework utilizing Information Communication Technologies

Pakistan's Power Sector is, and has been for many years, plagued by significant challenges. These include limited availability of reliable and affordable electric power, aging infrastructure, increasing cost of fossil based generation, and outdated policies and practices that lag behind those of modern utilities elsewhere in the world. Moreover, extremely low levels of investment in utility infrastructure are a huge barrier standing in the way of improving operating performance and facilitating improved outcomes to the end consumer. Everything in the world is going global and energy theft is following the trend. It is a known fact that electricity theft is a growing problem that continues to get worse. According to World Bank report in 2009, there is an annual worldwide electricity loss worth 220 billion USD due to electricity theft or technical problems with the grid.

Our team at the Center for Intelligent Systems and Network Research (CISNR) seeks to balance energy security, economic growth and environmental concerns through the implementation of an **Intelligent and Secure Electricity Distribution and Management System.** The solution is a governance tool that could alleviate Pakistan's power shortage by improving the performance of power distribution companies, strengthening the framework of the power sector, reducing losses, increasing revenues, and improving customer service. The solutions that we have come up with will address our energy crises by preventing illegal use of electricity, bringing people out of the misery they go through everyday due to this social evil committed worldwide.

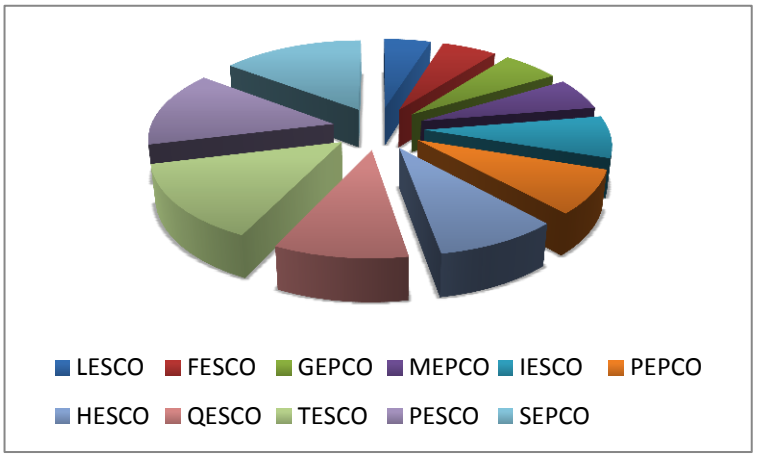
Challenges faced by the Electricity Infrastructure

The rising industrialization and population in today's energy starved era has led to an ever increasing demand for energy, the major portion of which is being used in electricity consumption. This leads to a rapidly rising cost of electricity due to which consumers have started stealing electricity by hooking up a wire (kunda) to overhead electricity cables, tampering with their meters or tapping power lines to avoid recording electricity usage. Power theft, being a major contributor for power deficit, represents huge revenue losses and incessant load shedding. The magnitude of the problem is abnormally large in Pakistan where legitimate customers bear the cost of illegal electricity and the power service becomes less reliable for paying customers. 35% of the total losses faced by PESCO, a major electric distribution utility, are due to electricity theft, representing more than 400 Million USD of annual revenue loss for 2.8 million users that they have. The annual revenue loss per user is calculated to be 143 USD. DISCOs losses increased by 73.94% from 2008 to 2012 and by a further 2.2% in 2013. If the prevalent situation is allowed to continue and the losses are not taken care of, Pakistan will have to face devastating consequences in future.

Growing in parallel are the rising concerns regarding the limited availability of fossil fuels, and the worldwide awareness about the environmental impacts of burning fossil fuels. This leads to the need for promoting renewable energy resources into the infrastructure. The electricity distribution system in our country is already challenged and unable to facilitate improved outcomes or keep a balance between utility supply and demand.

Effect of Electricity Losses on National Revenue

Division/Circles	Percentage Losses
LESCO	15.4
FESCO	18.2
GEPCO	18.9
MEPCO	19
IESCO	24.8
PEPCO	25.7
HESCO	29
QESCO	31.3
TESCO	45
PESCO	45.2
SEPCO	46.9



Our Solution

Our solutions overcome power deficit and consequently get rid of all the problems arising due to it. This is done through detection and isolation of electricity theft and providing a mechanism for electricity management. The solution offers:

1. A secure billing framework along with transparent data acquisition throughout the infrastructure that allows the monitoring of electricity infrastructure as well as real-time detection of malicious activities and unauthorized consumption at the distribution level.

2. The possibility of a complete billing framework without the use of meters. The solution could be an added functionality to the existing infrastructure which means that there will be no need to change, remove or replace the existing meters. Because meter readers will no more be required, it will result in controlled billing irregularities occurring due to electricity theft through the exploitation of meter readers who are bribed by the consumers.

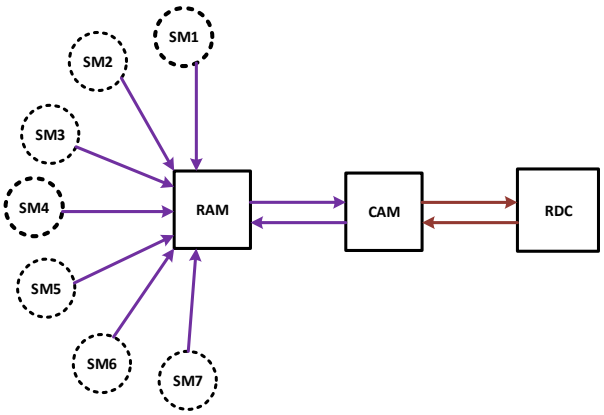
3. The prevention of electricity theft through efficiently securing the distribution lines. Whenever the illegitimate consumer taps the power line or hooks up a wire (KUNDA) to the line, the exact power line that has been tapped will be identified and located. The malefactor will be warned and if he continues the malfunction, will be dealt with high voltage spikes. As a result, damaged electrical appliances at his premises will be amongst the few penalties he will have to face.

I-DETECT

Our proposed framework consists of subscriber modules (SMs) that are installed at consumer lines to measure and record the electricity consumption. This information is then stored and sent to adjacent SMs and ultimately to the Regional Access module (RAM) through Zigbee. RAM serves as a concentrator

or an accumulator point for collecting data from SMs of specific vicinity. The Jennic module in RAM sends data that is received by the Jennic module in CAM. The communication between the two can be either through Zigbee, PLCC or GPRS. CAM further transmits it to the Regional Data Center (RDC) of that area. The data is transferred instantaneously to the GPRS module using Micro-controller unit. GPRS module transfers the data via Internet to the RDC that finally sends the data to the CDC.

RDC receives data from all AMs and stores it in a databank. RDC has monitoring and other smart applications installed, which provide the information regarding electricity usage information, anomaly detection, power calculation, statistic generation etc. A replica of the finalized data is maintained at the Central Data Center (CDC). However, a CDC also holds additional information about all RDCs. The diagram explains the interconnectivity of SM, RAMs, CAMs and RDC.



The distributed communication network has the capability to measure electricity consumption on the transmission and distribution lines, providing the data acquisition of the complete infrastructure, hence detecting malicious activities. Figure-1 shows the basic operation of the system.

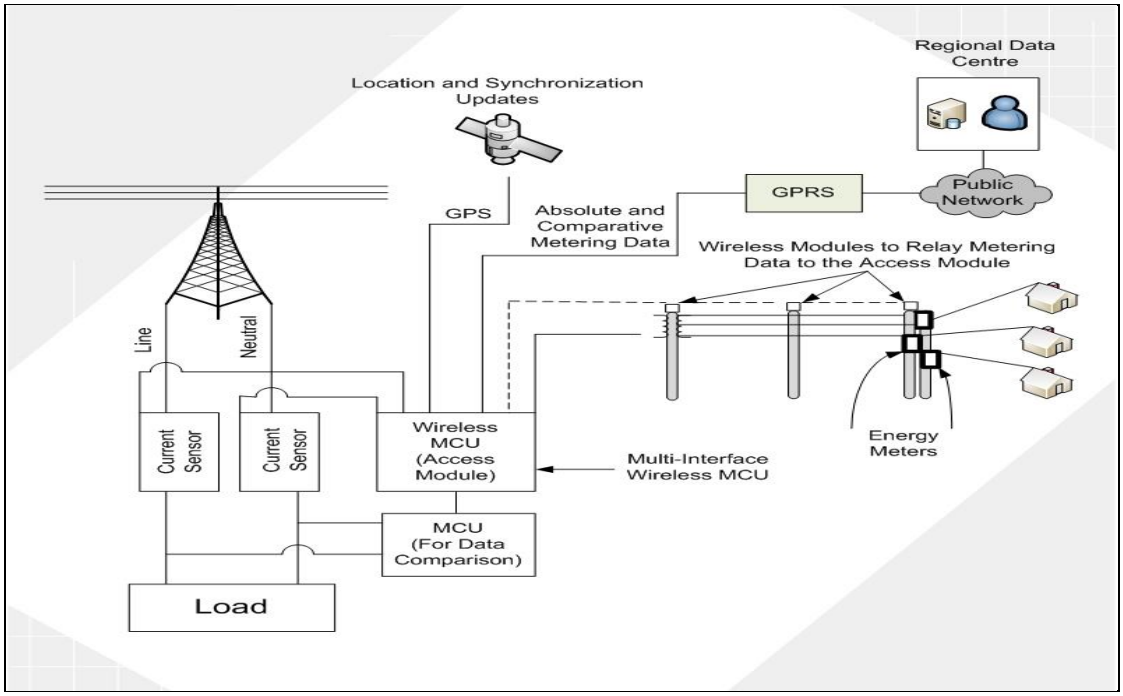


Figure-I: Basic operation of the system

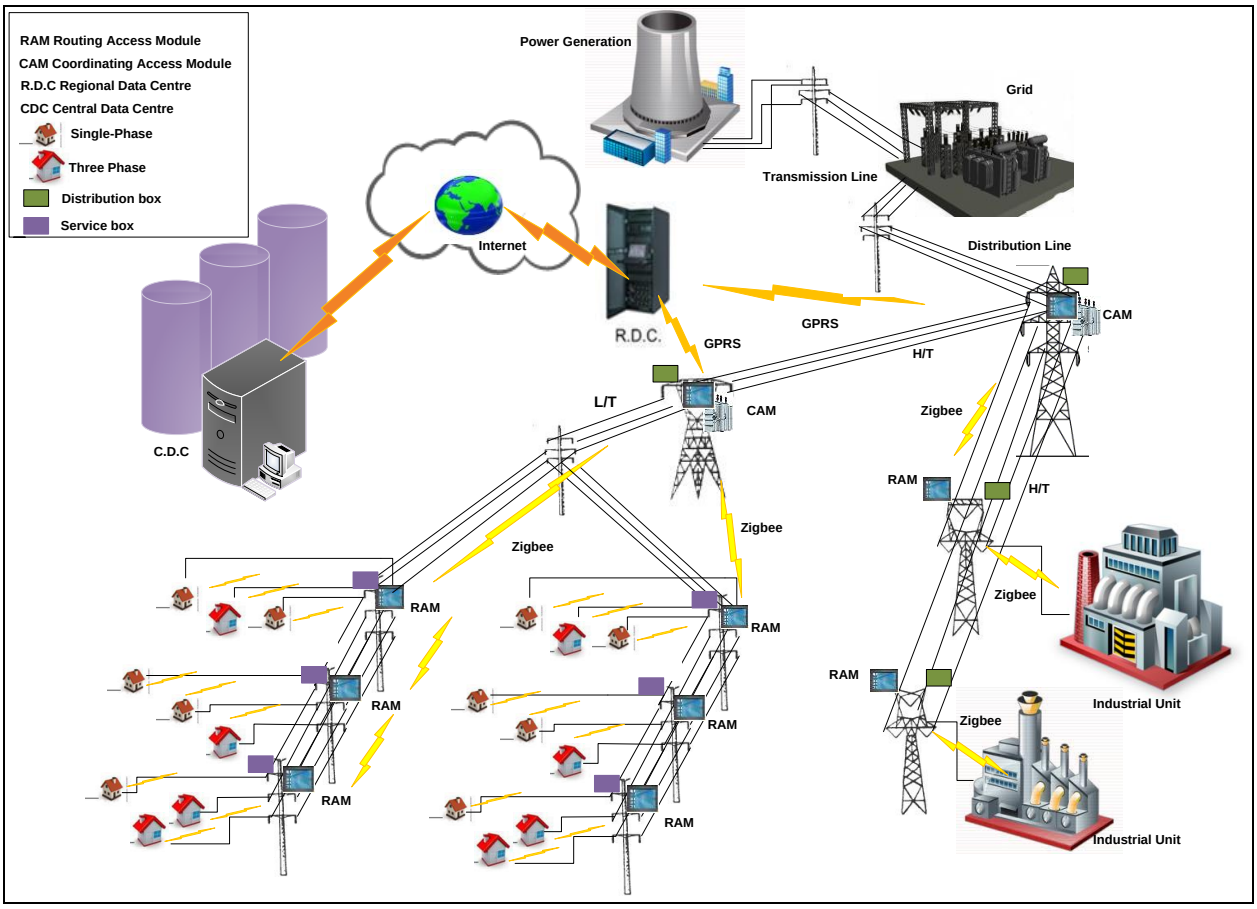
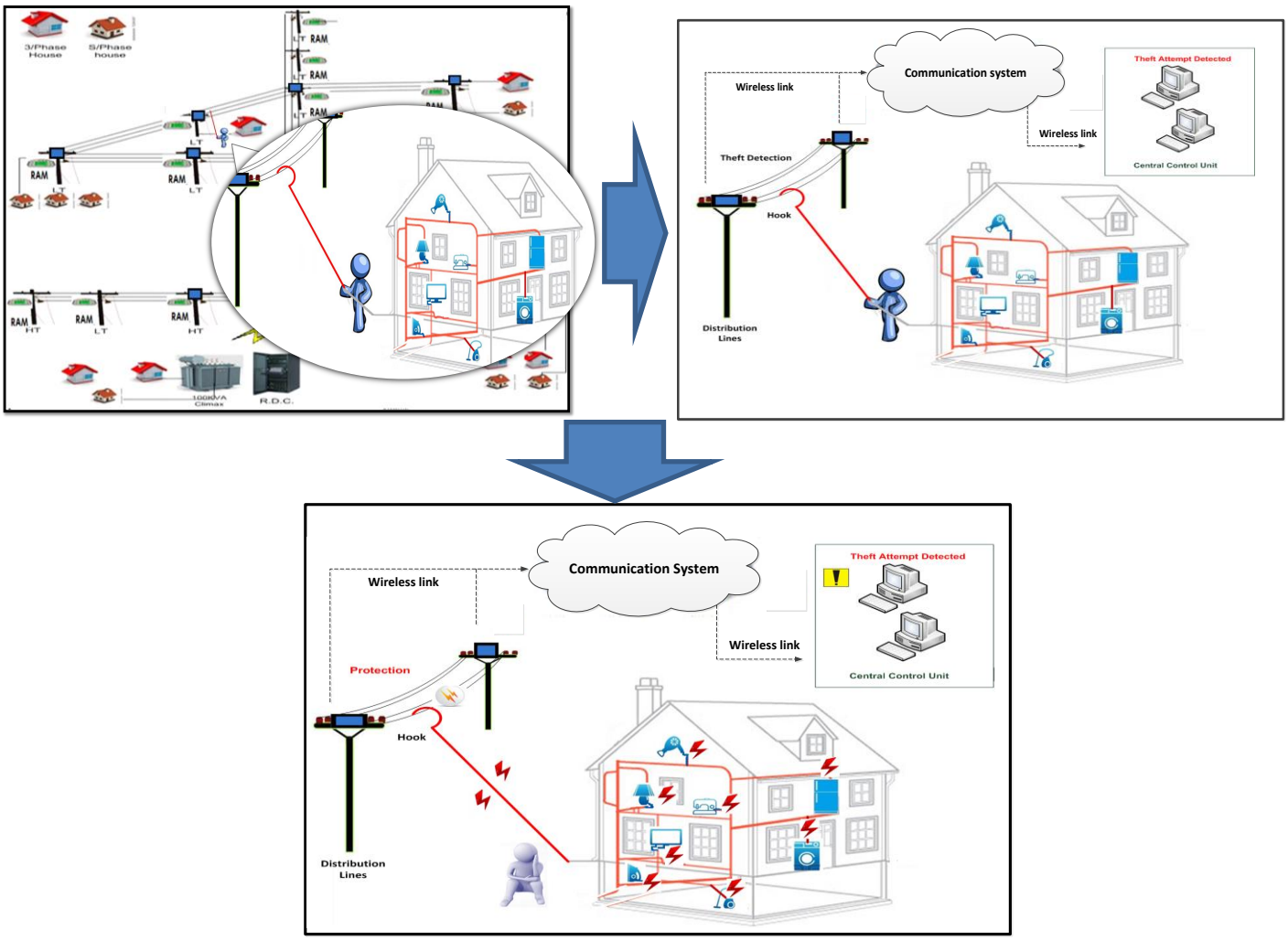


Figure-2: An overview of the system architecture depicting I-DETECT and I-SECURE

I-SECURE

Securing distribution lines is another smart approach towards the alleviation of electricity theft. The system architecture comprises of two main units i.e. distribution box and the service box. The distribution box comprises of a clipper and a high pass filter. The clipper clips off the high voltage from the 11KV lines and introduces harmonics of the fundamental frequency i.e.50 Hz. The distribution box also comprises of a high pass filter which passes only high frequency components to distribution lines. Thus a high frequency signal resides on the distribution lines. On an attempt to hook up the line, high voltage spikes are generated that can damage the electrical appliances at the user premises. The distribution lines concentrate at the service box which contains a band pass filter, to allow only the legitimate range frequency components to provide a safer and regular voltage to the normal users connected to the service lines. System architecture for both the layouts of the system is presented, with meters and without meters. For the systems with smart meters, the service box is mounted on the smart meters while for the systems without meters it is set up on the service point where users are connected through the service lines. An illustration of how electricity theft can be detected and prevented is show in the figure.



Subscriber Module

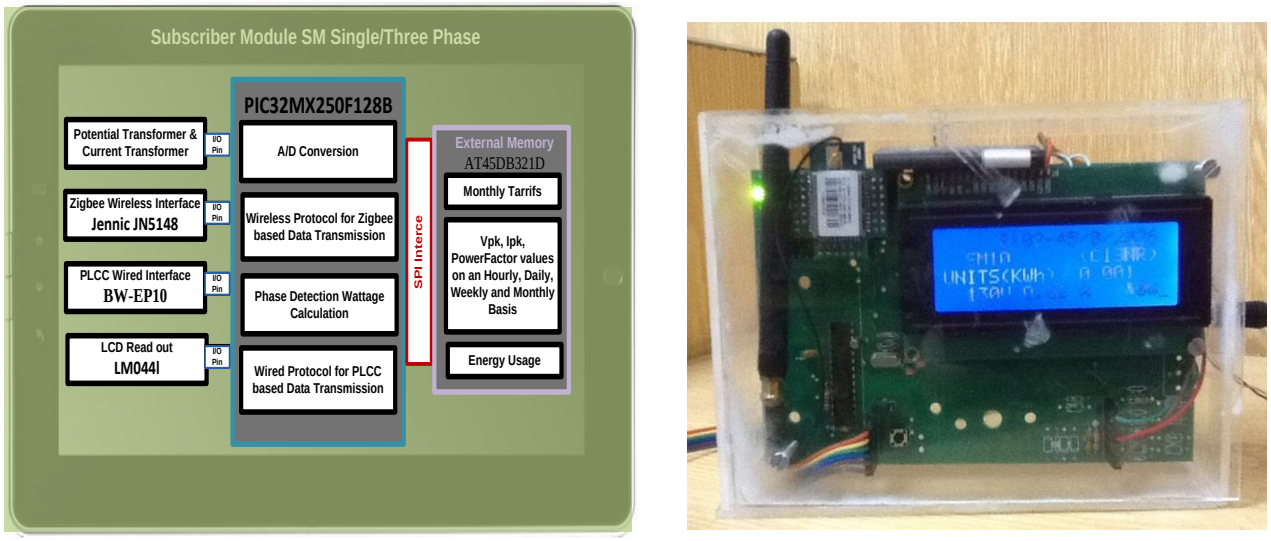
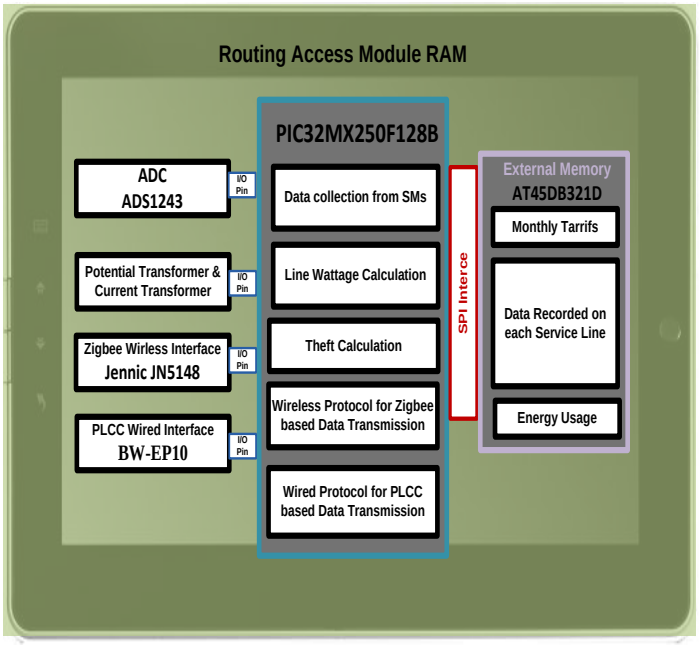


Figure-3: Block diagram and image of SM

Routing Access Module (RAM)



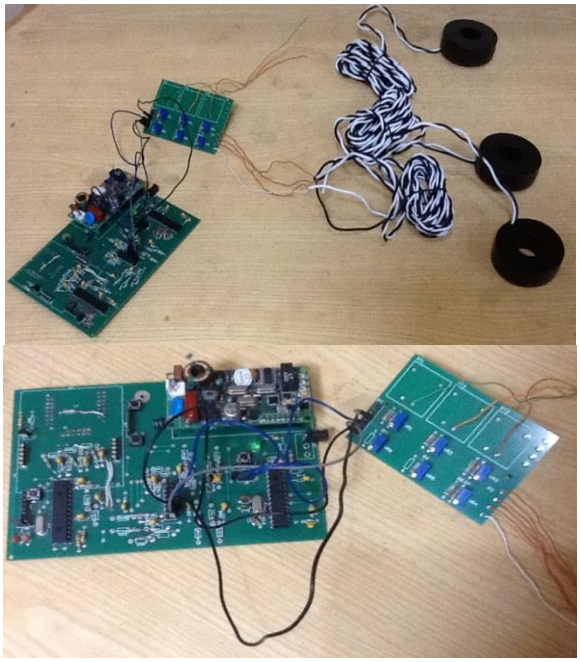


Figure-4: Block diagram and image of RAM

Coordinating Access Module

Currently CAM is capable to receiving data from RAM, transferring it to RDC and retrieving data from RDC using GPRS. Further transmission of data from CAM to RAM using Zigbee communication is in progress.

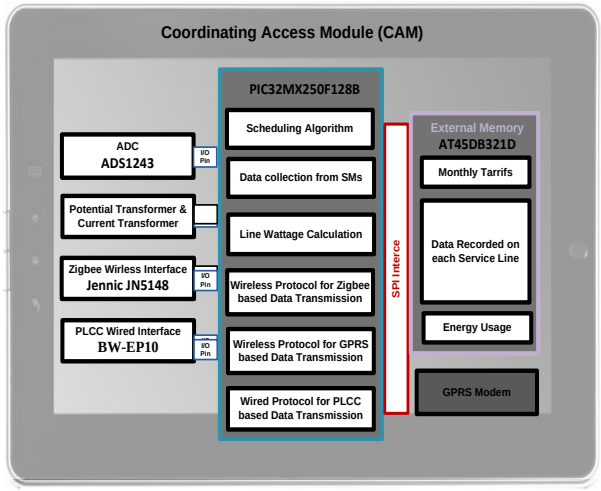


Figure-5: Block diagram and image of CAM

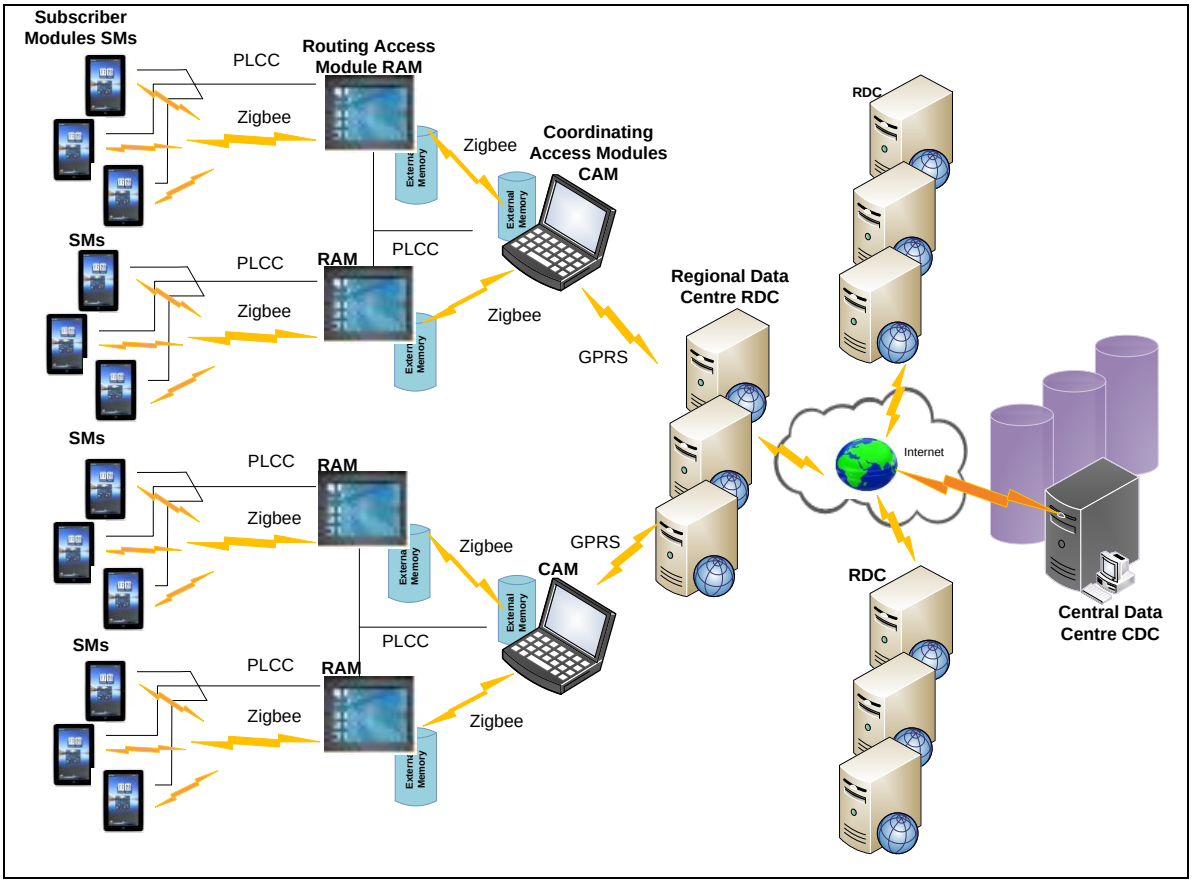


Figure-6: Connectivity between the modules

The solution resolves more than **90%** of non-technical losses by addressing:

- Theft done by Meter tampering
- Electricity theft from transmission and distribution lines
- Billing irregularities

It provides additional features of

- Multi tariff
- Demand response
- Remote controlled power on/off

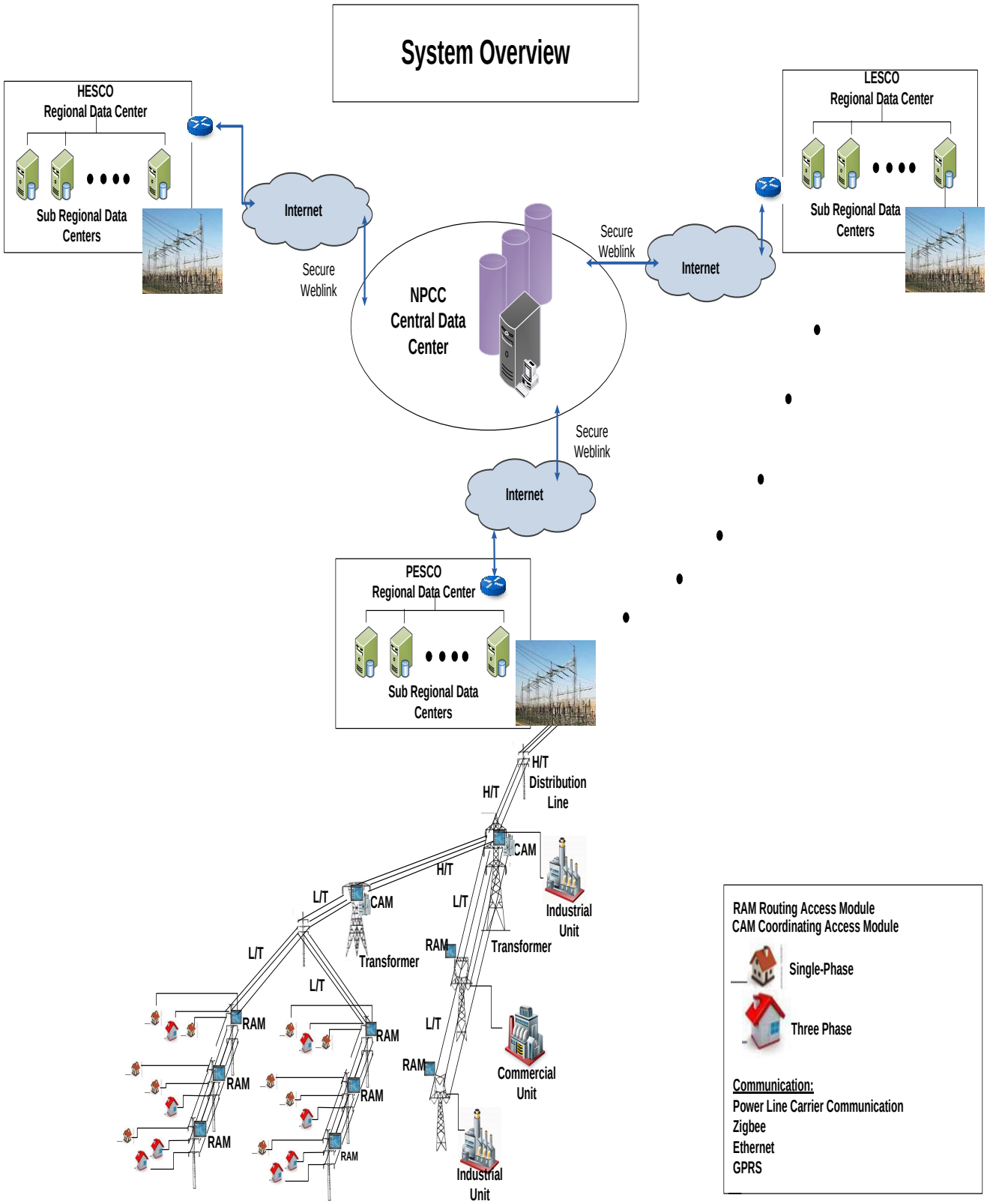


Figure-7: Overview of the system

Competitive Advantages

Individual line data acquisition	Less infrastructure , services, maintenance Cost	State estimation	Less bandwidth Required	PLCC, GPRS, Zig-bee, Ethernet
Modular features integration	Compatibility	Interoperability	Dynamic peak hours management	Short Circuiting info
Continuous Remote Monitoring	Real time energy management	Auto servicing in case of outages	Multi-phase power management	Anomaly communication
	Tracing aged wires	Prioritized anomalies management	Remote Circuit breaker Control	

Future Benefits

Once we have the system in place, it can provide us with several other benefits, due to the flexibility and the scalability that it offers. Some of the benefits are listed below:

1. Efficient management of the infrastructure will eliminate the need to secure electrical appliances through stabilizers since the system will no more be subject to voltage fluctuation.
2. Integration of dynamic pricing and in-house energy management model will allow each household to manage its own energy consumption and improve the electricity usage patterns.
3. Integration of renewable energy at distribution level by adding plug-and-play functionality to the system. The renewable energy resources adjust to variations in utility demand and supply, thus keeping a balance between the two.
4. Distributed energy management; efficient management of energy at demand side will considerably reduce the infrastructure losses.
5. Local generation; the use of small-scale generators at user premises will allow consumers (small communities-sub franchise plants for load shedding hours) to generate their own electricity and sell it back to the grid when supply exceeds consumption.
6. Real time demand management based on real time monitoring of electricity usage patterns at user premises.
7. Improved industrialization, leading to an improved social structure.
8. The process will lead to the development of new housing schemes and construction planning.
9. The need to store power during peak hours through UPS will be removed, reducing demand as well as reducing losses by 50%.

10. Reduction in demand during peak hours will consequently lead to the elimination of load shedding.

Future Prospects

The Pilot region implementation will need a start-up cost of 5 Million USD for 50,000 users. This cost will be recovered through benefits (revenue recovered from theft losses) within 2.2 years, even if one third of the losses are recovered in worst case scenario.

After the system is deployed, franchise models could be established at the generation, transmission and distribution end. Entering into franchise agreements with private corporations could be a smart and convenient way to extend the system to serve 20 million consumers, where the franchisee receives the profit through benefits. If 0.5 % of the revenue recovered is given to CISNR, it could be utilized for the sustainability of our research center where our efforts are not aimed at establishing business but at exploring emerging issues and fostering research and collaboration in the energy/power and various other sectors. The boost given to the industrial sector would create a large number of job opportunities for communities, significantly reducing the unemployment rate of the country. Because the solution is entirely novel, we expect huge revenues from international market.

We are committed to working towards a safer, brighter and more prosperous future for the people of Pakistan. We have therefore initiated efforts to achieve sustainable development by providing accountability, affordable energy, improved infrastructure, security of energy, enhanced power quality and a corruption free society. Our research will effectively impact national, industrial, corporate and family budgets, by offering substantial savings.