Telemetric Control of Traffic Lights Intersections in Ghana

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***Abstract* - This paper presents the current operation and maintenance of traffic light intersections and the design of a telemetry system to monitor and control traffic light intersections in the Accra metropolis. Telemetry is a technology that allows the remote measurement and reporting of information of interest to the system designer or operator. The design of a telemetry system constitutes the selection of a suitable hardware system and the appropriate software for the design of a human machine interface (HMI) to monitor the state of traffic light intersections and taking appropriate actions to resolve faulty traffic light intersections.**

***Index Terms* –Human Machine Interface, Loop detector, Signal head, Telemetry system, Traffic light intersections**

I. INTRODUCTION

A traffic light also known as a traffic signal or stop light, is a signaling device positioned at road intersections, pedestrian crossings and other locations to control the movement of vehicles and pedestrians. Traffic light intersections are employed country wide to improve the efficiency of traffic flow and reduce average travel time of both vehicles and pedestrians. Recent and continuing growth has resulted in increasing demand for travel on urban highways. Many highways are operating under congested condition throughout much of the day. Traffic congestion causes considerable cost due to unproductive time losses, accidents and also has a negative impact on the environment such as air pollution and fuel and on the quality of life, noise and stress. The economic consequences of traffic congestion are enormous. Due to the ever increasing need for transportation, there is more and more traffic congestion in developed and developing countries [1], [2], [3], [4]]. Traffic congestion continues to hinder economic and social development. The presence of traffic congestion costs a lot each year in the form of lost productivity. In the year 2000, it was estimated that drivers in 75 of the largest metropolitan areas of the world spent more than sixty eight billion dollars in person hours of lost time and wasted fund [5], [6]. In USA the cost of congestion is estimated to be 67 billion dollars each year [7]. This includes 3.6 million dollars in additional travel time and 5.7 billion gallons of fuel wasted while sitting in traffic [7]. Traffic delays result in increased air pollution, thus contributing towards the deterioration of the

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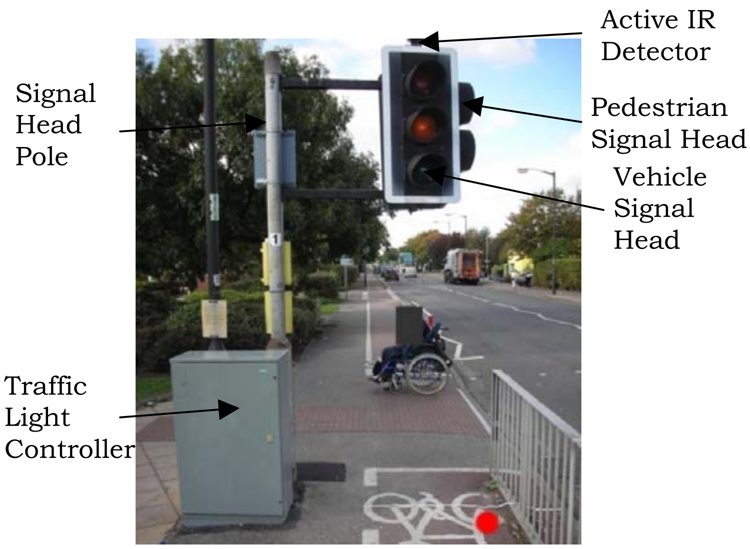

Fig.1: A modern traffic light

health and welfare of the citizen. A complete satisfactory scientific understanding of the phenomena of traffic congestion is still lacking [3], [4]. A reliable scientific description is crucial to study several scenarios and to take a good decision. Over the years, traffic lights have suffered and continue to suffer a lot of setbacks due to the frequent faults and the way of maintenance. Traffic lights normally have three main lights: a red light meaning ‘stop’, a green meaning ‘go’ and the amber light meaning ‘stop if possible’. Automatic control of interconnected traffic lights was introduced in March 1922 in Houston, Texas.

In Ghana, the maintenance of traffic signals is a fundamental aspect of the Department of Urban Roads responsible for the operation, maintenance, improvement and repair of all of the traffic signal installations.. At present there are 89 junctions and 4 pedestrian crossings controlled by traffic signals within the city of Accra. There are two main contractors employed to assist with the maintenance, Facol Roads Limited and Signal Limited. They both deal with technical faults such as replacing of fused bulbs in signal heads and push buttons, alignment of signal heads and poles, resetting of controller in times of malfunction, tracing and repairing of cables in manholes, signal heads and pole compartments. It was observed that the existing system of routine maintenance is very expensive over the years, time consuming and inherently inefficient. This problem calls for a highly efficient telemetric control system which will monitor all the traffic lights intersections and also establish some control over traffic lights intersections from a base station. This paper is intended for the design of a telemetry system through the selection of hardware system architecture and the appropriate software for the design of a human machine interface to monitor the state of traffic light intersections and taking actions to resolve faulty traffic lights intersections.

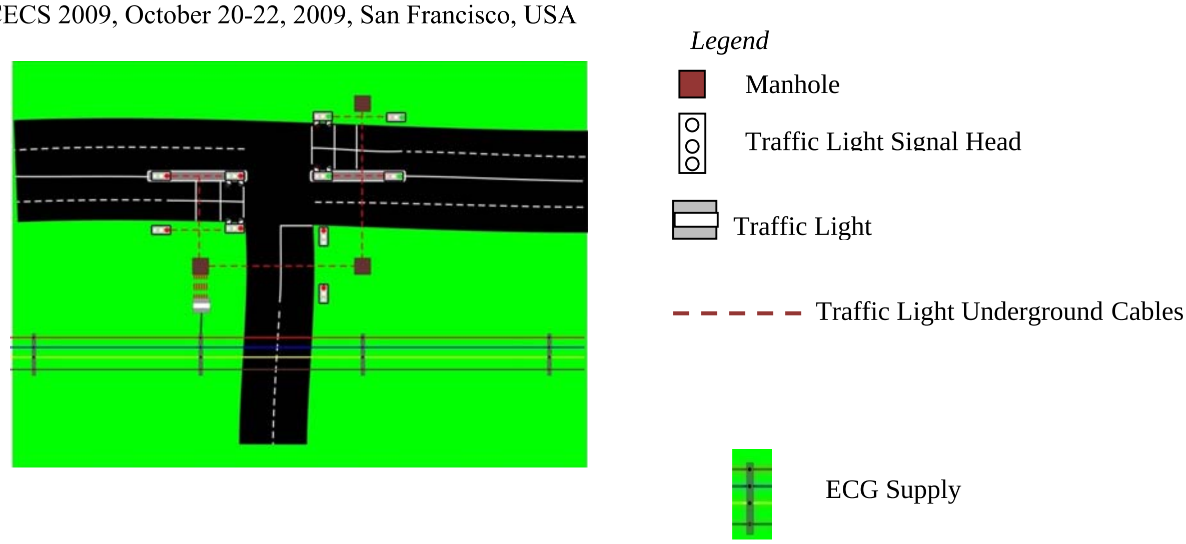

Fig. 2: Typical layout of a T-junction intersection

II. MATERIALS AND METHODS

Fig. 3 depicts the component parts of the traffic lights intersection system. The controller serves as the brain of the system, the sensor/transducer detects the presence of vehicles whilst human beings are detected by way of the pedestrian push button and the signal head acts as the actuator.

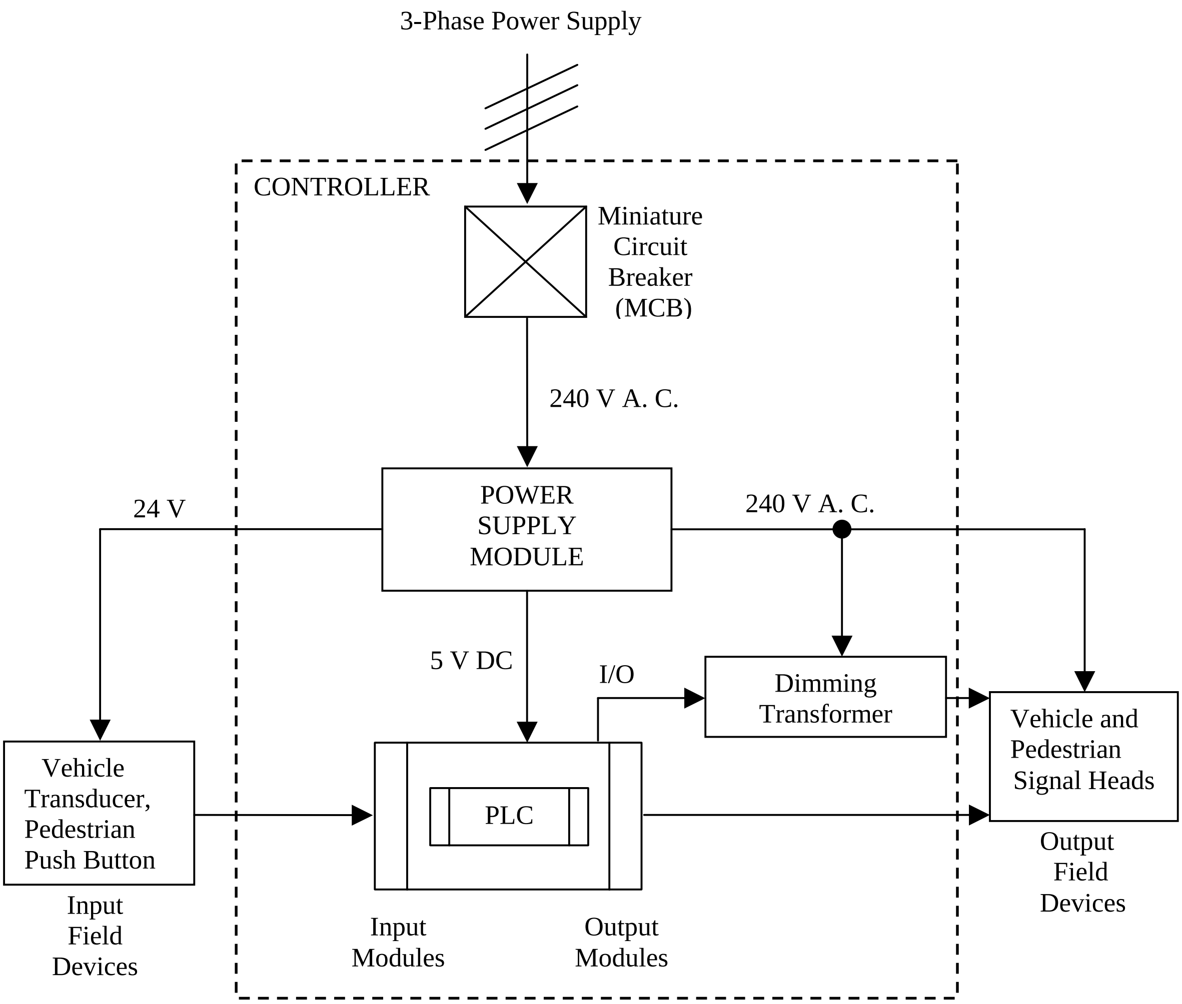

Fig. 3: Functional block diagram of a traffic light intersection system

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A. Input and Output Field Devices

The vehicle transducer is based on technologies for detecting vehicles such as microwave and millimeter-wave radar, active LED infrared radar, video image detection system (VIDS) and loop detector among others. Loop detectors are the most common form of detectors implemented in Ghana. They can be rectangular, circular, or diamond. They consist of an insulated electrical wire placed on or below the road surface. The loop is attached to a signal amplifier and a power source, creating an electromagnetic field in the area of the loop. The wire loop is excited at frequencies from 10 kHz to 200 kHz. In conjunction with pull box electronics, the loop becomes an inductor, whose inductance decreases whenever a vehicle or other larger metallic object passes over it or stops on it. The resulting inductance change generates a signal to a controller. A single loop of detector with a signal amplifier costs around $700.00 including installation [8].

Signal heads consist of signal faces that control traffic for specific movement in a single direction. In Ghana the most common signal heads are the vehicle 3-aspect and the pedestrian 2-aspect where their usual colours are solid red, yellow and green light and/or green/yellow turn arrows. A pedestrian push button assembly is for activating a signal generator to generate a signal at a street crosswalk. Both signal heads consist of respective number of 20 cm^2 signal faces (lanterns), standard type double insulation 230/12 V 50 VA transformers, 12 V 50 Hz 50 W 820 lumens 2,000 hrs life expectancy halogen bulbs, polished anodic electrolytic casing 99.9 % pure aluminium reflectors and polished glass lenses. It is installed in a manner that prevents it from overheating by the halogen bulb, which enables constant reflection of light upon the entire lens surface. In special cases, an arrow with the colour of the lens is created on a black background, only on the green lens. The vehicle signal head in particular is installed on a 2.5 m steel pole with the aid of bolts and nuts. This pole is mounted on a pole pedestal buried about 0.5 m into the ground. Proper alignment of vehicle signal heads and poles are ensured for proper vision to all road users. The pedestrian push button assembly has a rigid frame having a piezoelectric material of a solid state switch positioned across a central aperture, and an elastic sealing ring positioned in a groove surrounding the piezoelectric material. A button is secured to the rigid frame such that a seal contact portion of the button sealable rests against the elastic sealing ring. The pedestrians push button is installed about 1.2 m from the surface of the ground on a traffic light pole with the help of bolts and nuts.

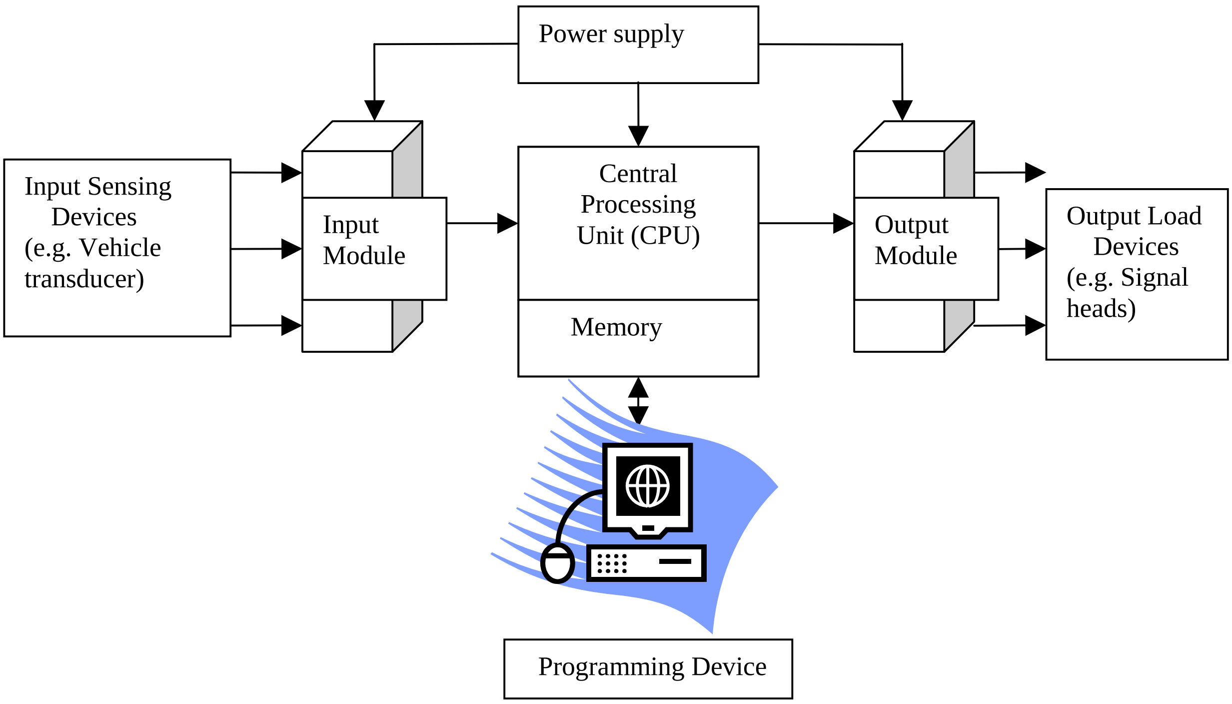

Fig. 4 Block diagram of a programmable logic controller

B. Traffic Lights Intersections Controller

The controller is mounted on a concrete pad. Traffic controllers use the concept of phases, which are directions of movement lumped together. For instance, a simple intersection may have two phases: North/South, and East/West and these phases are either controlled by controllers in fixed time mode or by a detector which is through the use of transducers. Although some electromechanical controllers are still in use (Trade Fair - Accra), modern traffic controllers are of programmable logic controller (PLC) technology. The typical controller as depicted in fig. 3. consists of miniature circuit breaker, power panel, programmable logic controller and the dimming transformer. The miniature circuit-breaker provides efficient and reliable protection for traffic light cables and the controller cabinet in traffic light installations. Three different tripping characteristics provide the ideal solution for all applications from cable protection up to the protection of controller cabinet [9]. The power supply module takes 240 V ac and distributes 5 V dc power to the PLC's Central Processing Unit, 24 V dc to the transducers and 240 V ac to both the dimming transformer and output devices. The dimming transformer is a single phase 240/110 V transformer, which in conjunction with the PLC reduces the illumination of the signal heads in the evening. This usually affects the vision of drivers. A programmable logic controller (PLC) is a specialized computer-type device used to control equipment in an industrial facility. The PLC provides soft wiring connections and flexibility between system devices as opposed to hard, inflexible, costly and time-consuming wiring of traditional traffic light control systems installations. All equipment are wired to the PLC and the executable computer control program stored in the PLC's memory provides the "wiring" connection between the devices. Soft wiring enables changes in the traffic light system to be made easily and cheaply. The PLC basically consists of the central processing unit, memory and the input/output modules as depicted in fig. 4. The programming device, detachable, is added to the PLC to achieve the needed programming functionality. The central processing unit (CPU) as the "brain" of the PLC retrieves, decodes, stores, and processes information from input devices such as vehicle transducers and accordingly executes the control program stored in its memory in order to generate the output signals to control field actuators such as the signal heads. The I/O modules are units with connection terminals to which the transducers and signal heads are wired.

III. THEORY OF DESIGN OF A TELEMETRIC CONTROL SYSTEM

A. Wireless Radio Telemetry System

Telemetry is a technology that allows the remote measurement and reporting of information of interest to the system designer or operator. Telemetry is invaluable in circumstances where the equipment is remote, inaccessible or increased accessibility goes with a health risk. Radio, as a means of communication, is the medium through which data at remote locations are reported wireless. Wireless telemetry is the wireless transmission and reception of measured quantities or data for the purpose of remote monitoring making use of a radio frequency system to implement the data link. It offers convenience and increased information accessibility to equipment or data located in hazardous and remote areas. A basic wireless radio telemetry system consists of an input transducer, the transmitter and receiving stations. A radio telemetry system could be categorized as local, centralized or distributed control.

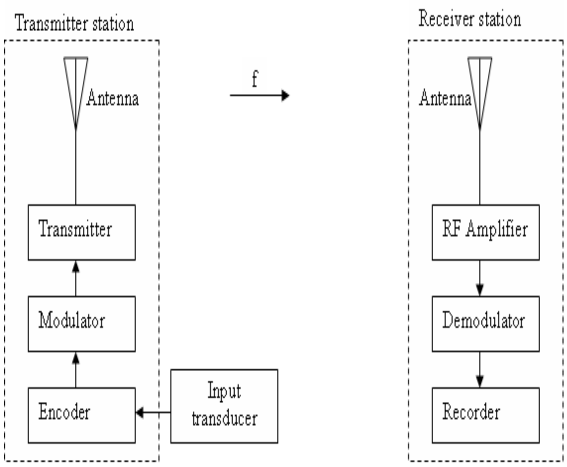

Fig. 5: Functional block diagram of a telemetry unit

Table 1 Frequency bands for transmission and reception of some radio modems [10]

Frequency Range, MHz	
Transmission	**Reception**
848 to 858	920 to 934
920 to 934	848 to 858
925 to 943	906 to 924
855	860
924	944

Transducers convert the measured physical quantity or data into a usable form for transmission. In a radio telemetry system, the transmitter and receiver have much in common with communications equipment whilst the transducers are unique to telemetry. The radio link can transmit an analog of the continuous variable being measured, or, with pulse-code methods, it sends the measurement data digitally as a finite number of symbols representing a finite number of possible values of the measurement signal at the time it is sampled. The range of a radio link is limited by the power radiated toward the receiver from the transmitter and by the sensitivity of the receiver. The wider the bandwidth, the more the effect from noise, and therefore the more transmitted power required for a detectable signal. Frequency plays an enormous role in radio communication coverage. Ultra-high frequencies (UHF) offer communication distances of around 25 Km to 100 Km and above with appropriate site locations and heights while unlicensed low band products (400 MHz) offer limited distances. Unlicensed spread spectrum devices with antennae offer distances of 10 Km up to 20 Km, with mobile phone coverage being country-wide. Satellite coverage can be "local" or "global" depending on the network and the amount of satellites employed and its purpose [10]. A reliable radio communication requires a highly reliable 'line of sight' path. Repeaters in conjunction with high gain antennae are used to give greater radio coverage.. Frequency bands for transmission and reception of some radio modems are given in Table 1

B. Radio Telemetry Unit

A radio telemetry unit (RTU) is a special purpose PLC with a modem connected to a radio transceiver and an antenna. The difference lies in the limited number of RTUs input/output arrangement as compared to that of a PLC. Thus, the selection criteria for a PLC apply to the RTU. Combination of both RTU and PLC in a complex system is possible. All RTUs are designed to allow the monitoring and control of remotely located equipment. By connecting two RTUs together via a radio or telephone link transfer of status information measured on one to another is possible. More complex networks allow several RTUs to be connected via a communications network to one master unit so that the remote sites can be monitored all at a convenient central location (such as the offices).

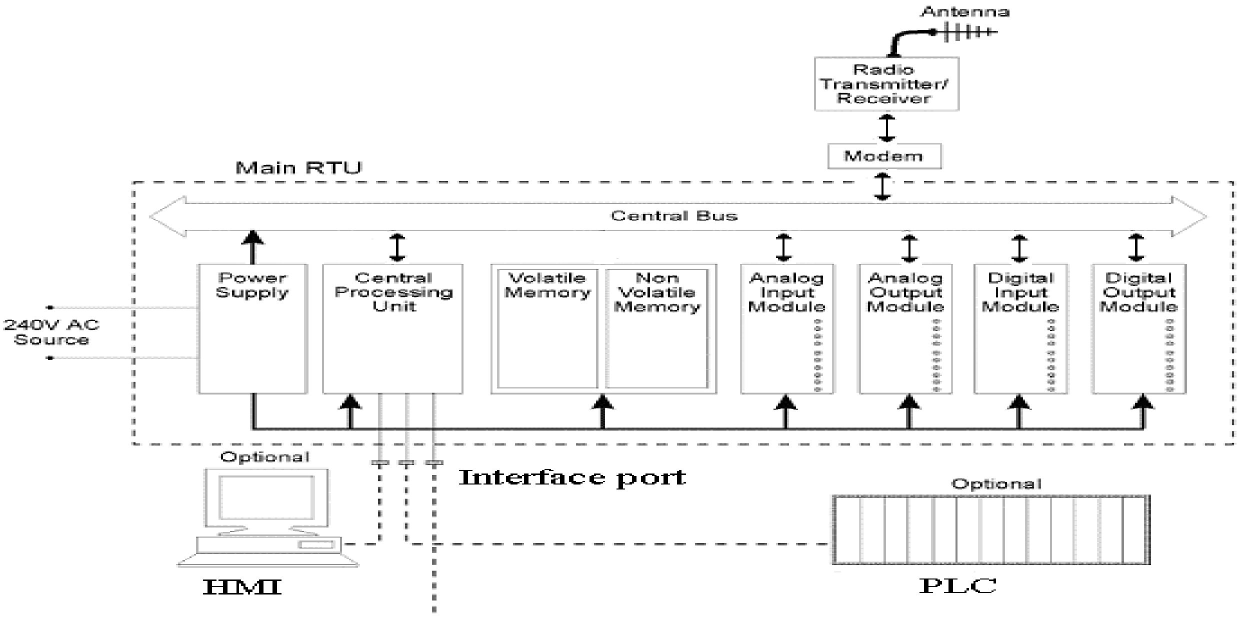

Fig. 6 Block diagram of a radio telemetry unit

The radio telemetry unit (RTU) is interfaced to a personal computer (PC) and programmable logic controllers (PLCs) via a non-protocol interfacing RS232 port (Fig. 7). Most RTUs use this interfacing medium while others use PCMCIA ports in addition to the RS232 which allows a range of PC cards to be inserted into the RTU to allow connection to ethernet networks. The radio telemetry system may typically be configured in either of two ways: either point to point (PTP*)* or point to multi-point (PTMP*)*. The PTMP has a master device which periodically reads and writes data between itself and several other slave devices. There can be only one master device in this type of system. The success of a telemetric control system using radio frequency largely depends on its transducer and transceiver unit. The transceiver is a dual purpose device that has the ability to transmit and receive data signals. Factors that influence the choice of a transceiver and antenna unit are sensitivity, selectivity, range and noise level.

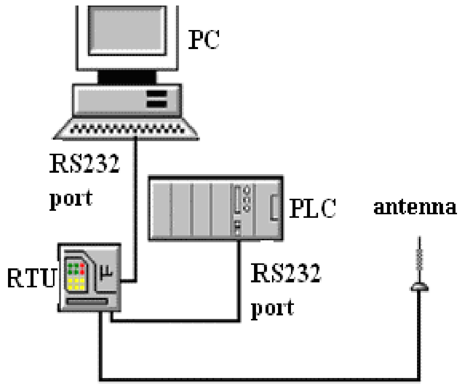

Fig. 7 Radio telemetry unit interfacing [10]

C. Local, Centralized and Distributed Control Radio Telemetry System

A local control radio telemetry system is a system in which sensors/transducers, a controller, and controlled equipment is within close proximity and the scope of each controller is limited to a specific system or subsystem. Centralized control describes a system in which all sensors/transducers, actuators, and other equipment within the facility are connected to a single controller or group of controllers located in a common control room. Locating all controls, operator interfaces and indicators in a single control room improves operator knowledge of system conditions and speeds up response to contingencies. Centralized control systems are only considered for small facilities. A distributed control system architecture offers the best features of both local control and centralized control. In a distributed control system, controllers are provided locally to systems or groups of equipment, but networked to one or more operator stations in a central location through a wireless communication circuit. Control action for each system or subsystem takes place in the local controller, but the central operator station has complete visibility of the status of all systems and the input and output data in each controller, as well as the ability to intervene in the control logic of the local controllers if necessary [11]. This is considered to be the most appropriate system because it easily fits into the current traffic lights intersection control system.

IV. PROPOSED DESIGN OF TELEMETRIC CONTROL OF TRAFFIC LIGHTS INTERSECTIONS

The proposed telemetry system presented in Fig. 8 includes master station, input-output signal hardware (transducers and signal heads), traffic light controllers, human-machine interface ("HMI"), communication link and software. The controller and the detector are the already existing ones in the traffic lights intersections system and they need not to be replaced.

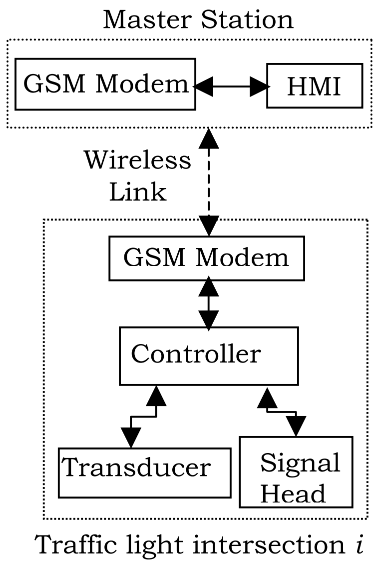

Fig. 8 Distributed telemetric control architecture for the control of traffic lights intersections

A. *Master Station*

The term "Master Station" refers to the servers and software responsible for communicating with the field equipment (traffic light controllers), and then to the human machine interface software running on workstations in the control room, or elsewhere. In these telemetry systems, the master station is composed of a single PC. Master stations have two main functions: to periodically obtain data from traffic light controllers and secondly to control remote devices through the operator station.

B. *C ommunication Link*

The communication link is provided by sixty four GS35 GSM Siemens modems. A GSM modem is a device that allows you to send and receive information over the GSM network with computers. Sixty-three of GSM modems are connected to the remote traffic lights controllers through an RS232 serial port interface on the controller and the last connected to the master station in the control room. The communication service will be provided by any of the GSM service providers in the country. The on site sixty three GSM modems will be sending fault messages from faulty intersections to the master station GSM for processing.

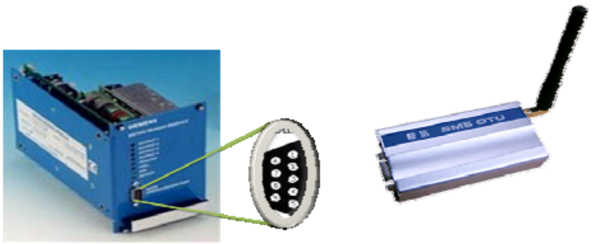

Fig. 9 GSM modem connection to traffic lights controller through RS 232 port

C. *GSM Network Structure*

The GSM network (Fig.10) is divided into three major systems as follows: the switching system (SS), the base station system (BSS), the operation and support system (OSS), and additionally, some functional elements.

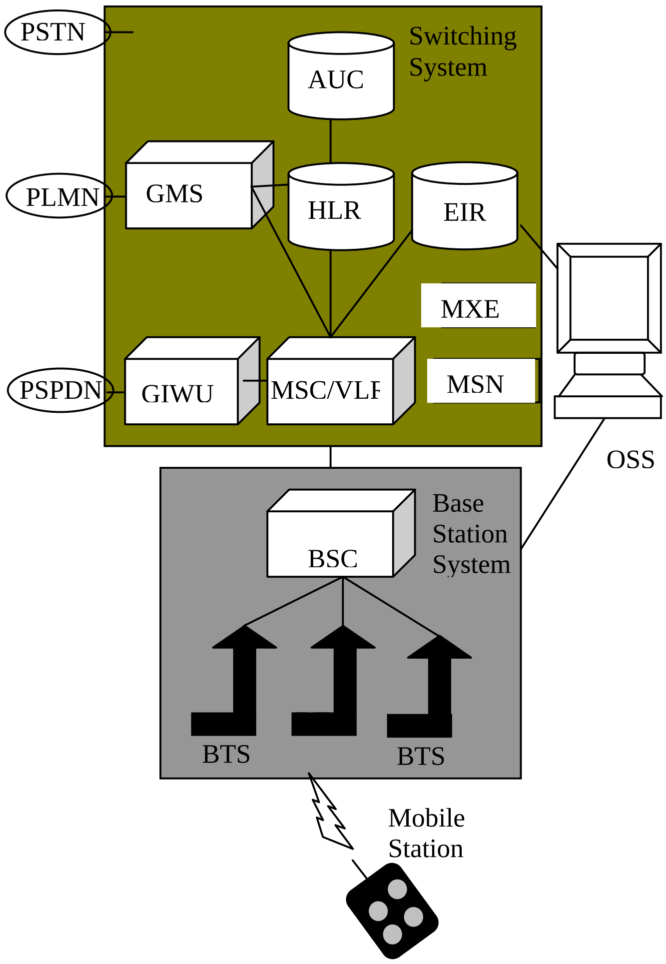

Fig. 10 GSM architecture

V. SYSTEM SOFTWARE

Resulting system software is a combination of individual softwares as presented in Fig. 11: Short Message Service (SMS) Server (ActiveXpert Software), Database Software (Microsoft Access), Dynamic Data Exchange (DDE) Server and Human Machine Interface (HMI) Software (RS View).
The SMS messaging framework enables on site GSM modems to send, receive and process SMS messages. The framework is designed to scan the GSM modem every five seconds for "fault" message and update the Microsoft access database software. Microsoft Access of the 2007 Microsoft Office system is a relational database management system which combines the relational Microsoft Jet Database Engine with a graphical user interface and software development tools. Access is used in this case to store messages from the SMS messaging server (ActiveXpert software) in codes of "01-99" in its database. The DDE is a Visual Basic based software created to aid two or more softwares to communicate with each other. That is, HMI software which is RS View based communicates with the database software (MS Access) through the DDE server software. The HMI is the apparatus which presents processed data to a human operator, and through which the human operator controls the traffic lights intersections. The RS View was essentially born out of a need for a standardized way to monitor and to control multiple remote traffic lights controllers. This software's interface is capable of showing the map of central Accra with corresponding animated traffic lights intersections. These animated traffic light intersections do change colour when the database is updated as a result of faulty remote traffic light intersections sending an SMS message to the master station.

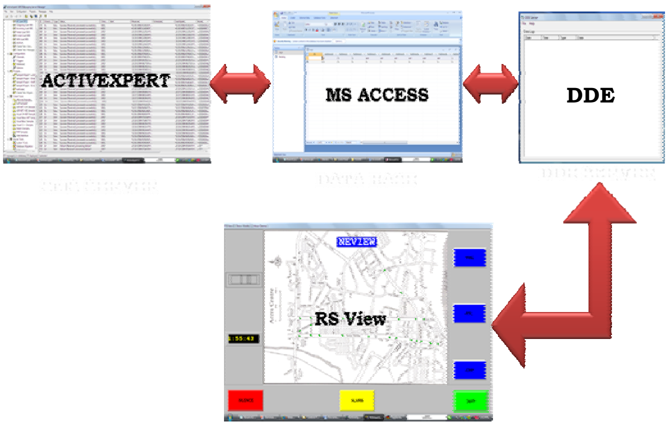

Fig. 11: Software architecture

VI. APPLICATION TO THE ACCRA TRAFFIC LIGHTS INTERSECTIONS

The cost analysis involved weighing the total expected costs of existing way of maintaining traffic lights intersections against the proposed improved method of maintaining traffic lights intersections in the Accra municipality. The cost of implementing this project will be run for two years.

Table 2 shows cost of existing method of maintaining traffic lights intersections. It takes into account items used in the routine maintenance of traffic intersections in Accra. The grand cost of maintaining the existing traffic lights intersections was found to be GH¢ 29,520.00. Table 3 then summarized cost of improved method of maintaining traffic light intersections. It takes into account the items used in the routine maintenance in Accra and various quantities and cost. The grand cost of maintaining the improved traffic lights intersection is found to be GH¢ 15,472.00. The net profit of improved system of maintaining traffic light intersections in Accra is realized by subtracting the cost of the improved method from the cost of existing method of maintaining traffic lights intersections. The differences in cost are given by:

GH¢ 29,520 - GH¢15,472 = **GH¢14,048 (US$ 8,780.00)**

Table 2 Cost of maintaining existing traffic light intersections

Item	**Quantity**	**Unit cost (GH¢)**	**Total (GH¢)**
Fuel	9 gallons	4.00	25,920.00
Maintenance	1	150.00	3600.00
Grand Total			29,520.00

Table 3 Cost of maintaining the improved traffic light intersections

Item	**Quantity**	**Unit cost (GH¢)**	**Total (GH¢)**
Fuel	0.73 gal	4.00	2,088
Maintenance of Vehicles	1	12.00	288.00
Software	1	2,7000	2,700.00
GSM Modem	65	150	9,750.00
SMS Message	3650	0.04	146
Master Station	1	500	500
Grand Total			15,472

VII. CONCLUSION

Telemetric control of traffic light intersections will introduce a more effective way of carrying out maintenance. Upon calculating the cost of establishing or carrying out this project, it was realized that the new system has high initial cost. However, the running cost will be very low if this project is implemented.

RECOMMENDATIONS

To minimize faults on site, all halogen signal heads should be replaced with LED signal heads because of its almost everlasting life span. Also, since the telemetry system is more beneficial compared to the existing system, we recommend that the project be adopted and implemented by Facol Roads Limited and other traffic light maintenance companies as it will go a long way to increase their efficiency and profit margin.

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