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Review article

# Parametric survey on cross-layer designs for wireless sensor networks

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The network model presented through OSI and TCP/IP comes in different encapsulated modules, which provide the abstract view of layers to its adjacent module. The encapsulations of layers make a profound effect on network efficiency, quality of service (QoS), communication overhead, latency, etc. In addition, it is hard to implement it in wireless sensor networks (WSNs) scenarios. To overcome these architectural effects, cross-layer designs (CLDs) opted which shows promising improvement. It enables information sharing among the non-adjacent layers and compensates the performance and reliability. It is able to provide application-specific on-demand services in WSNs due to its simplicity and flexibility. Moreover, it helps in prolonging network lifetime, improvement in QoS and security of WSNs. In this article, classification made on the parametric improvement achieved by adopting CLDs. The performance metrics co-related to others such as strict latency affect QoS, transmission energy optimization affect the network lifetime, routing affect latency and much more. Therefore, the classification made with the dominated metrics. In this context, CLDs potential had led to include an application-oriented proposal that classified separately due to its specific dominance. Furthermore, the challenges in CLDs with potential resolution has given. We summarize our article with the observation made during the study and the suggestion for improvement on existing methods followed by the discussion on some open problems.



**Contents**



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## 1. Introduction

Wireless communication has established itself as convenient, less expensive and less maintains service on data-exchange for several occasions to provide end-to-end hassle free services. The communication networks of today is advance in many ways and gone through several refinements as of analog voice calls of 70's to current high speed reliable and efficient data transfer [1]. The evolution of wireless is from ad-hoc networks of availing high speed data connectivity to service-oriented sensor network and from broadband technology to LTE, WIFI and 5G networks. WSNs gained worldwide attention has revealed a remarkable potential to provide on-demand services to end-to-end users as of its application area is concern. In [2,3] as mentioned, the development in MEMS technology, communication and digital electronics have enabled the development of small size, multi-functional, energy efficient sensors to provide communication within the specific range. WSNs is being used in several areas of application such as environmental monitoring, defense surveillance, health-care etc. Many kind of literature available to help to understand the problem domain of WSNs and energy, which become the crucial resource. Moreover the challenges, developments and potential direction which could provide road-map for futuristics achievement [2–6]. The primary task of sensor is to gather information in different kind of geographical location based on the needs of application, while in most of the scenario the geographical nature of deployment is remotely located and not accessible in a regular manner [2,3,7–9]. The very first sensor network deployment was presented in 1999 [10] through wireless communication and power supply used in sensors was analog current in nature. The nature of power supply in sensors now days are mostly battery power, therefore the energy efficiency became very crucial part of the sensor due to its inaccessibility of the deployment area and its geographical nature. Moreover, some other QoS aspects such as reliability, delay/latency, and throughput, etc. services are also seeks very important attention at the time of deployment itself. The open system interconnection (OSI) [11] model is widely used in conventional communication architecture which provides networking framework to implement the protocols in seven layers. Each layer has its definitive predefined functionality for communication and allows interaction or procedure calls among the adjacent layers but it does not allow interaction in between the non-adjacent layers. The working principle of traditional layered protocols based on OSI model was originally designed for wired communication. The abstraction and encapsulation constraint of each layer from others was to maintain modularity and provide services with information exchange [1–3,11–13]. The nature of encapsulation provided by traditional layers maintains modularity in network deployment. Yet, it also prevents to share some necessary information among the layers in protocol stack which create hindrance in many application and causes negative impact on the efficiency of networks. For example, the Medium Access Control (MAC) sense the neighbor node that suppose to forward the data is highly occupied due to traffic load but repeatedly sensing for that particular node to free instead of data forwarding [14], which addressed in the later part of this text. Its became highly desirable to propose a CLPs stack to overcome the limitation and provide better network management in terms of energy, QoS, and so on. The interactions between different non-adjacent layers allow the communication architecture to work as a system instead of the different protocol stack and it is termed as cross-layer design (CLDs). Energy became a very critical resource in WSNs, while the traditional protocol stack not designed for WSNs hence, new energy efficient protocol need for all layers of protocol stack [1–3,13,15–20].

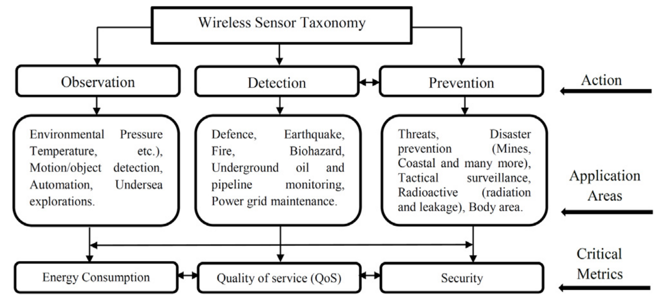


**Fig. 1.** WSNs taxonomy, application and performance metrics.

The very first concept for CL architectural design for wireless network proposed in [15]. It exhibits that how CLDs can maintain the abstraction of each layer with the accomplishment of the modularity. Meanwhile, several attempts taken to provide the solution for specific metric of wireless networks [21–26]. In [21], CLPs has presented for multihop wireless network for joint rate control and centralized scheduling in MAC. In [22], CLPs for jointly rate control and distributed scheduling. Moreover, CLPs for congestion control, routing and MAC scheduling for network stability with fairness has given [23]. In [24], transport and physical layer balancing through CL design proposed, which further leads to congestion control of MAC and power control of physical layer. Also joint consideration for congestion control [25] and rate control with end-to-end fairness [26] has discussed. Amount of data and nature of nodes imply significance changes in network configuration. This motivation leads to develop some of CLDs for multimedia data rate [27,28], mobile wireless network [29], 3rd generation [30] and 4th generation wireless network [31].

In this paper, we emphasize CLPs in WSNs predominantly on the terrestrial sensor network. Moreover some of the techniques often used in underground and underwater environment is mentioned worthwhile to cover the prospective of taxonomy in the text. The CLPs works in specific manner as either it obligated to follow centralized or distributive methodology to handle the important issues of WSNs [20] such as energy, NL, routing, channel scheduling and QoS (application specific ) etc. In Fig. 1, categorization has made based on most often action, application and performance metrics that governs the WSNs. A wireless sensors resides at application domain, usually perform continuous observation to report back the activities in observational area or start sensing when certain events occurs followed by predefined actions for prevention. Each application governs by specifics sets of performance metrics or individuals in that context, the taxonomy presented in this paper for CLPs in WSNs has based on performance metrics itself. In addition, Table 1 has given the abbreviations used in this work, Tables 2–6 has given to embellish the taxonomy with detailing the attributes such as system models classification, objectives, technology and validation technique adapted and Table 10 has listed the potential directions to overcome the limitations or challenges posses by CLDs.

The structure of this survey can be summarize as describing the fundamentals of cross-layer design in WSNs (Section 2), taxonomy and framework for CLPs in WSNs (Section 3). Highlights of the protocols and mechanism that used CL approach in WSNs and present and extensive survey based on parameters and application