

A Survey : Embedded Systems Supporting By Different Operating Systems

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ABSTRACT

In these days, embedded system have an important role in different Fields and applications like Network embedded system , Real-time embedded systems which supports the mission-critical domains, mostly having the time constraints, Stand-alone systems which includes the network router etc. A great deployment in the processors made for completing the demanding needs of the users. There is also a large-scale deployment occurs in sensor networks for providing the advance facilities, for handled such type of embedded systems a specific operating system must provide. This paper presents some software infrastructures that have the ability of supporting such types of embedded systems.

Keywords: Embedded System, Operating System, Real-time Processing, Linux, QNX

I. INTRODUCTION

Embedded system are computer systems designed for specific purpose, to increase functionality and reliability for achieving a specific task, like general purpose computer system it does not use for multiple tasks. Now days there are many types of distributed embedded system increased the performance and usability. A system is embedded not only by hardware it have also embedded software.

There are a variety of embedded systems used in industrial, commercial areas. e.g Mobile Phones and different type of Network Bridges are embedded used by telecommunication systems for giving better requirements to their users. We use digital cameras, MP3 players, DVD players are the example of embedded consumer electronics. In our daily life its provided us efficiency and flexibility and many features which includes microwave oven, washing machines dishwashers Embedded system are also used in medical, transportation and also used in wireless sensor network area respectively [64, 65, 66, 67, 68] medical imaging, vital signs, automobile electric vehicles and Wi-Fi modules [69, 70, 71]

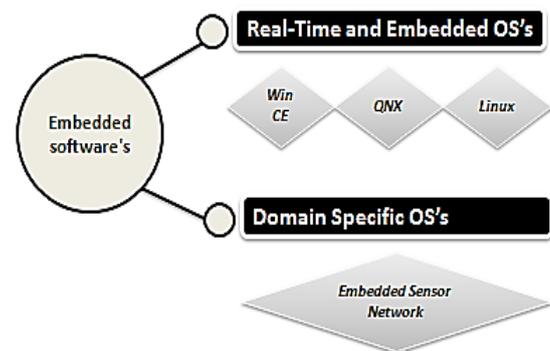


Figure 1: Taxonomy of Embedded Software's

II. METHODS AND MATERIAL

2. Embedded software organization for embedded systems:

Embedded systems needs higher reliability because most of them are safety critical systems therefore consists on microprocessors. Some embedded system are designed from scratch and software specifically developed for those are devices. Different high level programming languages, which fulfils the requirements of that particular software are used by the programmer, having

the ability of exception handling and should have the reliable code [1, 72, 73]. Software can be designed using off the shelf components. Operating systems are the example of the reusable software components, which doesn't developed from scratch.

Software should not the platform-dependent it should be the capability of evolvability either it would run on the LAN or shared wide-wide area network. It also should be guaranteed that it provide the same services with respect to the environment of the user, according to their requirement. Accuracy and precision are important when environment changes.[2]

Embedded operating systems are developed for handling the particular application. There for OS used in embedded systems is most different than the general purpose OS used in our desktops computers. And these systems also have the real time properties according to the system requirements. Such types of operating systems are divided into two types, embedded operating system and real time operating systems.

2.1 Real time and embedded operating systems:

Embedded systems are mostly used Real-time operating systems, QNX [3], WinCE[4], Vxworks [5] are most widely used embedded operating systems. All embedded devices having operating system which can be supported by that device. An embedded real time device must have the RTOS. Embedded OS having reliability, portability and configurability are the important features in it. RTOS should show the accurate logical results, in specially safety critical systems because in accuracy May loss causes of lost a life like air craft system. The operating systems giving above support the large systems consisting on higher CPU and memory size. And also multitasking, TCP/IP networking, memory protection can be supported by it [74, 75, 76, 77, 78].

Window NT [6] is not real time operating system, but due to industrial need, window NT should be evolved for achieving some features of real time systems.

Linux operating system also not supported real time system for this purpose RTAI (real time application interface) [7] are designated which is an extension of Linux. Embedded Linux is also an evolution in Linux but it doesn't support real time application like RTAI.

Commercial off-the-shelf components used [8] for

achieving the target of distributed real time and embedded systems, such as mission critical dynamic domains which includes the radar processing, online financial trading etc. Clock synchronization [9] is an important feature of distributed real time operating systems. Clock synchronization should be fault tolerated for giving the accuracy. When CPU [10] is highly loaded and unexpected interrupts disturbed time due to this RTOS exceed their limits then more energy will be consumed by it as compared to the normal execution.

In heterogeneous environment embedded systems are more complex in sense of their reliability and security which in more demanding feature in this environment. Over a decade performance of ICT is main focus of researchers. But recently, security and reliability become the higher issue. Some projects proposed by [11] used the micro-kernel for reliability and dependability, [12] proposed Minix OS and [13] suggest the L4 OS for higher reliability.

2.1.1 WinCE

November 1996 in handheld PC window CE was introduced. There are many extensions of windows CE. Embedded systems have the restriction of space. Windows CE developed for achieving the given aim. This is a thin client operating system supports priority inheritance and developed for embedded applications like entertainment and communication [14].

Window CE is real-time operating systems which have the functionality of operate the embedded 32 bit processor. Zigbee is an embedded system based on ARM having the serial communication functionality which improves the transmission area and reliability of helicombe used as wireless sensor network module. Due to ARM device has of low power consumption (now a days it is an issue of green computing) high performance and lower cost. It also includes the functions data receiving, showing, and the ability of information storage [15].

In zigbee application design algorithms implementation for serial communication and interface design it uses the embedded visual C++. Different languages used by programmer for different algorithms [16, 17, 79, 80, 81].

Systems depending on window CE have 4 layers 1)

Hardware layer includes all the hardware used in those systems, such as processors. 2) Operating system is an interface for users. 3) Applications layer consists on the applications which depend upon different types of performances on the device. 4) Hardware support layer consists on interaction between hardware and OS used by that system [18,19].

Basic needs of storing, manipulating, retrieving the data have every operating system. These operations can be performed by replicating the data on a backend server. Enterprise and personal application used such type of database respectively for applications which provided financial services and web-based like entertainment, games etc. For this purpose a relational database like SQL server used by window CE. The constraints on space using by the program is followed by this engine. The architecture of SQL engine includes query optimization, relational storage (transaction and indexing) and backend data replication [20].

Another system used master slave architecture call Computerized Numerical Control (CNC) using embedded real time operating system.[21]

2.1.2 Linux:

Few years ago the use of Linux in embedded device became most popular. People needs accessing their own account anywhere so it is used as a functional OS in networked systems. Linux have an important feature of flexibility, because we can interrupt in kernel at runtime and unload a module. Linux is open source so its code is worldwide available, also portable and scalable. It can run on every processor and also license free.

Differentiability between the hardware make the operating system most sophisticated (mobile devices, servers etc). Different configurators are developed for the

purpose to ensure the validity and user guidance. Too many configurators are developed like for feature models commercial configurators [22] have been designed. Open source configurators [23,24,25]are also available. For one-size-fits-all kernel configurators, grows for the purpose of increasing performance [26].

For purpose of bidirectional broadcasting the different devices like internet and PSTN are used. So there should be an embedded operating system used. Linux is open source. So it modified the kernel of embedded Linux for achieving the goal [27]. In FPGA embedded system a Linux operating system is used. Different fault injection techniques used for checking the reliability of the system [28]. Linux is quite good for different microprocessors due to robustness because it is more scalable and reliable [29].

2.1.3 QNX:

QNX software system limited designated the QNX for real time operating systems. It have the functionality of processing the medical machines, telecommunication, and electronic devices. The requirements of these devices are higher reliability and safety because all are attach with our daily life, also having the features of scalability and flexibility. It is small and fast.

Medical devices like calculated the genetic methodology can some time distributed on multi processors due to large amount of data. It is also provide fully networked applications and provide higher performance in a real time environment. The draft standard 1003.4 which acts in real time environment is structured for distributed transparent environment. It is uses with microkernel processors in real time environment which consists on the services of UNIX and POSIX [30].

Table 1: A Comparison table of QNX, WinCE, Linux [31]

Features/OS	QNX	Window CE	Linux
Processor	X86-based	32-bit address based	ARM, Strong ARM, MIPS, Hitachi SH, x86-compatible
Memory	Small kernel, 12 KB	For kernel and communication support needs 350 KB	For Configurable kernel needs 125-256 KB

Architecture	Used Micro-kernel	Hieratical based	Layering structure based
Scheduling algorithm	Priority based, same priority then FIFO, Round Robin	Priority based time slice algorithms / 8 priority levels	Priority and quantum based / 4 classes of threads
Preemptive/ Non-preemptive	Pre-emptive	Pre-emptive thread scheduling	both
Interprocessor communication	Message passing	Message passing	Original linux IPC mechanism
Network support	Low-Level Network	Internet protocols (FTP, HTTP servers)	All current internet protocols

2.2 Domain specific OS:

This section describes the software infrastructure like operating system for specifically developed for one domain called the sensor networks.

2.2.1 Embedded Sensor Network:

Wireless technologies helped in making the low cost sensor devices [32] which have the low power consumption. Sensors devices like Ad-hoc network have thousands of small devices spread across a large area and communication made through the sensing ability of that device by passing messages to each other. Military also use the sensing devices. The sensing networks its tracks every moment of enemy in war. If damage all other network due to an emergency situation sensor ad-hoc network are easy and quickly to establish and maintain. It also helped in making the large embedded sensor network. Embedded computer having sensors or actuators, for interaction with the local environment, in inexpensive way [33]. WSN's (wireless sensor networks) have the constraints so its protocols requirement designed with new applications. For long life time of a

network it's necessary to have the capabilities of low power consumption and device complexity. Balance between communication through a network is necessary requirement (signal processing should be in a manner). Many applications of WSN is enabled by IEEE 802.15.4 [34]. A light weight operating system Contiki divided into two parts core and loaded programs is used for Wireless sensor networks. It has the event-driven kernel and also have the dynamic unloading and loading of different services. it is preemptive in multithreads environment and implemented in C language[35]. Some micro sensor nodes are Mote/TinyOS [36],Meta cricket [37], MIT location aware cricket [38], Bluetooth based sensor nodes[39] which operate with the help of

MANTIS [40] operating system have the ability to manage multithreading, aggregation and time sensitive tasks. For supporting the multi-hop networking, a reservation-based NanoRK [41] real-time operating system is used. Pixie [42] OS is also used in sensor networks for resource managing in different applications. LiteOS [43] have the ability of managing WSN's.

Table 2: Comparison of OS's Used in Sensor Networks.[44,45,46]

Features/OS	NanoRK	MANTIS	TinyOS	LiteOS	Contiki	SOS
Real-time support	Yes	No	No	No	No	No
Architecture	Monolithic	Layered	Monolithic	Modular	Modular	Modular
Communication protocol	Depends on socket based	MAC and COMM	Two multi-hop protocols 1.TYMO 2.dissemination	File consisted	uIP, TCP/IP protocol, Rime and both versions of IP, 4 & 6	Message based
Static/dynamic Memory management	Static management with no protection of memory	Dynamic memory management and no protection	Static Memory protection and management	Dynamic Management and protection of memory	Dynamic memory management and no protection at	Dynamic Management and protection of memory

Language support	C	C	NesC	LiteC++	address spaced C	C
Scheduling algorithm	Harmonized and Monotonic based algorithms	Priority based classes	First in first out	Round robin	Priority based interrupts	-
Resource sharing	Mutexe and semaphores	semaphores	Through virtualization	Sharing can done by preemptive synchronization	Through Serial Access	-
Modals of programming	Thread driven	Thread driven	Event and thread driven	Thread and event driven	Event and protothreads driven	Event driven

III. RESULTS AND DISCUSSION

3. Characterizations of embedded systems:

Embedded means that a system inside another system which work as a small and specific part of that system. Different embedded systems have different functionalities therefore there is no need to include all functionalities in an embedded system.

As we mentioned above the sensors are also embedded systems having a small processor, which having the ability of computation of physical environment like pressure, temperature etc. Embedded systems are divided into two categories which are given below.

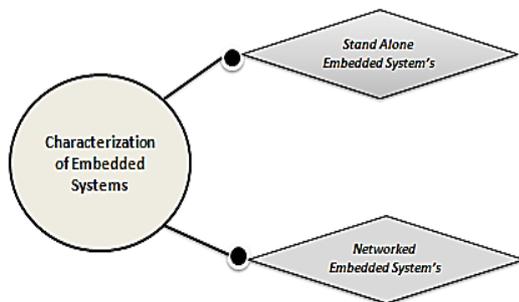


Figure 2 : Types of Embedded Systems

3.1 Standalone embedded systems:

Users just give an input and the gets the desired output generated by the system are called stand-alone systems. Now these systems are said to be as system on chip and is the intellectual property. SOC's offers multimedia processors or DSP's application which needs the requirement of highly performance and embedded functionalities.

Some Standalone system includes the electronic

consumers. CE divided into three types, Low-end

devices are normally inexpensive cheap processors and System on Chip devices having the minimum memory like ROM (256 KB). Mid-range devices having memory of almost 1 to 2 MB, like digital camera etc. High-end consumer devices having the memory up to 32 MB , devices like smart-phones are included in it.

3.2 Networked embedded Systems:

There are many types of NES's some form these systems are network embedded system technology (NEST) , network systems for embedded computers (EmNETS), Distributed real time embedded (DRE). Communications between functionally Distributed nodes which can be embedded are connected through the wireless/wired medium. it achieves the goal of interaction with environment by some actuators and sensing devices.

Paper [47] represents the general network embedded systems which includes distributed and real-time embedded systems, embedded systems and sensor systems. The reconfigurable, ubiquitous, and networked embedded systems called RUNES [48] develop a proگرامing platform to for developing architecture of the software's used in NES's.

Embedded systems mostly make there computations on the devices which make for other purposes. It is not necessary that all devices are connected and usually not a mobile device. It having one server, and have wired connection.

Sensor Networks have a famous example of wireless sensor network. It gets a great deployment of various types of applications in industrious environment and in our daily life, including health and military applications.

Sensor network[49] consist on the small , low power consumption machines which have the ability of concurrent execution of reactive programs that must operate with the constraints of space and low power. Different programming model can be supported by NesC compiler which analyzes the overall program, also maintained the inline function and reliability. NesC and tinyOS used by many of sensor networks. The key challenge for wireless network embedded systems is power supplying. It can be done by solar energy [50] several factors given in the paper which should be understandable.

Distributed real-time and embedded systems are mostly time critical. In different conditions which are time and life critical systems should must have the accuracy like aircraft systems.[51]

A NIST Net[52] emulation tool is used for experiments on the different network protocols and performance of the network.

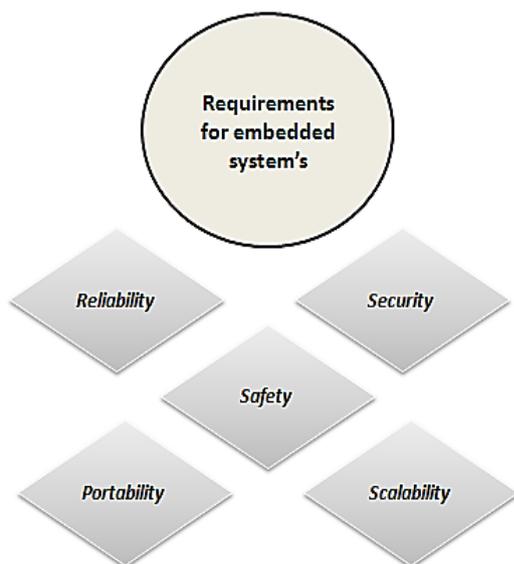


Figure 3 : Requirements in Embedded Software's

4. Requirements of embedded systems:

There are two types of requirement in software engineering. Functional requirements define the function of a software component. Describe the set of inputs and generate the desired output. Non-Functional requirements are requirement which is used for judgment of operation of the system rather than the given behaviour of the systems also called qualities of system. There are some requirements of embedded systems are given below.[53]

Reliability: The ability of a system which regularly perform their specific task on demand and on perfect time. No faults occur called the system reliability. A study of software reliability shows that there can be tolerated six-fifteen bugs per thousand lines codes according to this LINUX has 2.5 million lines of code and window XP has double of this code so according to the software reliability study window XP kernel has almost 30000 bugs which make it unreliable and in secure. Micro kernels have the higher reliability but lower performance than monolithic kernels. May be it come back in near future due to reliability [54].

Embedded system should be highly reliable because fixing the fault in embedded system is highly challenging task. In the performance requirement of a system reliability is the main feature [55].

Portability : A system should have the portability means if the system is developed in one environment it should execute in other environment with very minor change. Portability and adaptability is an important feature of embedded system [56,57].

The internal quality of a system or system software is portability, which includes Adaptability, Installability, Co-existence, Replaceability and Compliance [58].

Safety : Some embedded systems are safety critical which should not harm the human life like aircraft system, or insulin pump system which is life critical. System safety is defined by engineers as risks [59]. In a paper XtratuM [60] is designated for completing the requirement which are safety critical. Another CESAR [61] methodology provides a platform in safety critical application in different domains.

Security : In new electronic devices data security is very critical task includes computer, mobile phones etc. All the stages of an embedded system design from scratch to their development should be secure [62]. There is a large rang of embedded systems which have the issue of security for data manipulating, storing and sending etc. In networking security [63] protocols should be included for safe transmission of data.

Scheduling algorithms is failed to do the certain task in embedded systems because many of them ignores the security requirement. The given paper [64] applied the

time constraints and security on the periodic task scheduling algorithms used in embedded systems. Scalability, upgradability and fault tolerance are also requirements for embedded systems.

IV. CONCLUSION

As the above study of different software's which runs on embedded systems should have the requirements of safety and security. But many of them don't have the requirement and not support the real-time constraints and ability of fault tolerance. Research going on in these days, make the software's of embedded systems more reliable and include all the requirement of normal system. Network embedded systems are security critical for secure communication. The comparison of the sensor network OS's are given which shows the abilities and support that can be handled by the system. In these days, It is a challenging task that OS's used in network embedded systems should fulfil all the requirements like other systems.

V. REFERENCES

- [1] S.S. Maurer, "A survey of embedded systems programming languages, "Potentials, IEEE , vol.21, no.2, pp.30,34, Apr/May 2002.
- [2] J. A. STANKOVIC" Strategic Directions in Real-Time and Embedded Systems", ACM Computing Surveys, Vol. 28, No. 4, December 1996.
- [3] Dan Hildebrand, "An Architectural Overview of QNX", Proceedings of the USENIX Workshop, 1992.
- [4] Window CE(2008), Microsoft Windows CE, <http://www.microsoft.com/windowsce/embedded/>
- [5] Gerstlauer, A.; Haobo Yu; Gajski, D.D., "RTOS modelling for system level design," Design, Automation and Test in Europe Conference and Exhibition, 2003 , pp.130,135, 2003.
- [6] Ramamritham, K.; Greenberg, S.; Gonzalez, O.; Sen, S.; Shirgurkar, S., "Using Windows NT for real-time applications: experimental observations and recommendations," Real-Time Technology and Applications Symposium, 1998. Proceedings. Fourth IEEE , vol., no., pp.102,111, 3-5 Jun 1998.
- [7] Dozio, L.; Mantegazza, P., "Real time distributed control systems using RTAI," Object-Oriented Real-Time Distributed Computing, 2003. Sixth IEEE International Symposium on , vol., no., pp.11,18, 14-16 May 2003.
- [8] Douglas C. Schmidt. "Middleware for Real-time and Embedded Systems," COMMUNICATIONS OF THE ACM, /Vol. 45, No. 6, June 2002.
- [9] Kopetz, Hermann; Ochsenreiter, Wilhelm, "Clock Synchronization in Distributed Real-Time Systems," Computers , IEEE Transactions on , vol.C-36, no.8, pp.933,940, Aug. 1987.
- [10] Baynes, K.; Collins, C.; Fiterman, E.; Ganesh, B.; Kohout, P.; Smit, C.; Zhang, T.; Jacob, B., "The performance and energy consumption of embedded real-time operating systems," Computers, IEEE Transactions on , vol.52, no.11, pp.1454,1469, Nov. 2003.
- [11] Liedke, J. "On μ Kernel Construction", In: Proceedings of 15th ACM Symposium on Operating Systems Principles, December, pages 237-250, 1995.
- [12] Tanenbaum, A.S.; Herder, J.N.; Bos, H., "Can we make operating systems reliable and secure?," Computer , vol.39, no.5, pp.44,51, May 2006.
- [13] Heiser, G., Elphinstone, K., Kuz, I., Klein, G. and Petters, S. "Towards trustworthy computing systems: taking microkernels to the next level," ACM SIGOPS Operating System Review, 41(4), July, pages 311, 2007.
- [14] A.arnab. "using Microsoft window embedded operating systems on desktop machine in a laboratory environment", October 2003.
- [15] Jiang Min, "A Design of Embedded Terminal Unit Based on ARM and Windows CE," Electronic Measurement and Instruments, 2007. ICEMI '07. 8th International Conference on , vol., no., pp.2-336,2-340, Aug. 16 2007-July 18 2007.
- [16] Nick Grattan, Marshall Brain. "Windows CE3.0 Application Programming". Prentice Hall PTR, 2000.
- [17] Douglas Boling. "Programming Microsoft Windows CE .NET, 3 rd ed", Washington. Microsoft Press. 2003.
- [18] Xuan Lin, Hu Chen. "Design and implementation of analog display on an embedded platform", Chinese Journal of Electron Devices, Editorial Dept of the Chinese J. Electron Devices, China. Vol. 29, No.2, pp 447-450, June 2006.
- [19] An-Hsiang Wang, Yueh-Yuan Lai, Cheng-Tung Sun. "Effects of Palm and WinCE menu-design

- for PDA on users' operating performance and subjective preference", *Displays*. Elsevier. UK. Vol.26. pp. 97-102, April 2005.
- [20] Seshadri, P.; Garrett, P., "SQLServer for Windows CE-a database engine for mobile and embedded platforms," *Data Engineering*, 2000. Proceedings. 16th International Conference on , vol., no., pp.642,644, 2000
- [21] Suhua Xiao; Di Li; Yizong Lai; Jiafu Wan; Shouting Feng, "An Open Architecture Numerical Control System Based on Windows CE," *Control and Automation. ICCA 2007. IEEE International Conference* , 2007.
- [22] D. Beuche. Modeling and building software product lines with pure::variants. In *Proceedings of the 2008 12th International Software Product Line Conference (SPLC '08)*, page 358, Washington, DC, USA, 2008. IEEE Computer Society.
- [23] M. Antkiewicz and K. Czarnecki. FeaturePlugin: feature modelling plug-in for Eclipse. In *Proceedings of the 2004 OOPSLA workshop on eclipse technology eXchange (eclipse '04)*, pages 67{72, 2004
- [24] C. Kastner, T. Thum, G. Saake, J. Feigenspan, T. Leich, F. Wielgorz, and S. Apel. FeatureIDE: A tool framework for feature-oriented software development. In *Proceedings of the 31st International Conference on Software Engineering (ICSE'09)*, pages 611{614, Vancouver, Canada, 2009.
- [25] M. Mendonca, M. Branco, and D. Cowan. S.P.L.O.T.: software product lines online tools. In *Proceeding of the 24th ACM SIGPLAN conference companion on Object oriented programming systems languages and applications (OOPSLA'09)*, pages 761{762, New York, NY, USA, 2009.
- [26] O. Koren. A study of the Linux kernel evolution. *ACM SIGOPS Operating Systems Review*, 40:110{112, 2006.
- [27] S-P Moon, J-W Kim," Embedded Linux Implementation on a Commercial Digital TV System", *IEEE Transactions on Consumer Electronics*, Vol. 49, No. 4, NOVEMBER 2003.
- [28] S.Monson,MikeWirthlin," A Fault Injection Analysis of Linux Operating on an FPGA-Embedded Platform", *Hindawi Publishing Corporation International Journal of Reconfigurable Computing*, Article ID 850487, 11 pages, 2012.
- [29] Joel R. Williams," Embedding Linux in a Commercial Product", 1999.
- [30] Dan Hildebrand, "An Architectural Overview of QNX", *Proceedings of the USENIX Workshop*, 1992.
- [31] Catherine Lingxia Wang, Bo Yao, Yang Yang, Zhengyong Zhu," A Survey of Embedded Operating System".
- [32] Tubaishat, M.; Madria, S.K., "Sensor networks: an overview," *Potentials*, IEEE , vol.22, no.2, pp.20,23, April-May 2003.
- [33] Heidemann, J. and Govindan, R. (2004), *An Overview of Embedded Sensor Networks*, In: *Handbook of Networked and Embedded Control Systems*, SpringerVerlag
- [34] C. Buratti ,Andre, D. Dardari, R.Verdone ," An Overview onWireless Sensor Networks Technology and Evolution", *Sensor*, page 6869-6896, 2009.
- [35] Dunkels, A.; Gronvall, B.; Voigt, T., "Contiki – a lightweight and flexible operating system for tiny networked sensors," *Local Computer Networks*, 2004. 29th Annual IEEE International Conference on , vol., no., pp.455,462, 16-18 Nov. 2004.
- [36] J. Hill, R. Szcwcyk, A. Woo, S. Hollar, D. Culler and K. Pister, "System Architecture Directions for Networked Sensors" in *Proceedings of Ninth International Conference on Architectural Support for Programming Languages and Operating Systems (ASPLOS)*, (November 2000).
- [37] Martin, F.; Mikhak, B.; Silverman, B., "MetaCricket: A designer's kit for making computational devices," *IBM Systems Journal* , vol.39, no.3.4, pp.795,815, 2000.
- [38] N.B. Priyantha, A. Chakraborty and H. Balakrishnan," The Cricket Location-Support System", *ACM Proceedings of the 6th annual international conference on Mobile computing and networking*, Pages 32-43 2000.
- [39] M. Leopold, M.B. Dydensborg and P. Bonnet," Bluetooth and Sensor Networks: A Reality Check", *Proceedings of the 1st international conference on Embedded networked sensor systems*, Pages 103 – 113 ACM New York, 2003.

- [40] S.BHATTI, J CARLSON, HUI DAI, J.DENG, ROSE, A.SHETH." MANTIS OS: An Embedded Multithreaded Operating System for Wireless Micro Sensor Platforms", Journal Mobile Networks and Applications Volume 10 Issue 4, Pages 563-579 , august 2005.
- [41] A. Eswaran, A.Rowe, Raj jkumar," Nano-RK: an Energy-aware Resource-centric RTOS for Sensor Networks", Proceedings of the 26th IEEE International Real-Time Systems Symposium, 2005.
- [42] k. Lorincz, Chen, J. Waterman, G.W.Allen, M.Welsh," Pixie: An Operating System for ResourceAware Programming of Embedded Sensors",proceedings in ACM ISBN Virginia, USA, 2008.
- [43] Q. Cao, T. F. Adbelzاهر, and J. A. Stankovic, "The LiteOS operating system: towards Unix-like abstractions for wireless sensor networks," in Proc. ACM/IEEE IPSN, 2008.
- [44] Wei Dong, Chun Chen, Xue Liu," Providing OS Support for Wireless Sensor Networks: Challenges and Approaches", IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 12, NO. 4, 2010.
- [45] D. Manjunath," A Review of Current Operating Systems for Wireless Sensor".
- [46] M. O. Farooq and Thomas Kunz." Operating Systems for Wireless Sensor Networks: A Survey". Sensors , 11(6), 5900-5930, 2011.
- [47] FP6-IP-RUNES (2005) D5.1 Survey of "Middleware for Networked Embedded Systems", January 2005.
- [48] Costa, P.; Coulson, G.; Mascolo, C.; Picco, G.P.; Zachariadis, S., "The RUNES middleware: a reconfigurable component-based approach to networked embedded systems," Personal, Indoor and Mobile Radio Communications, 2005. PIMRC 2005. IEEE 16th International Symposium on , vol.2, no., pp.806,810 Vol. 2, 11-14 Sept. 2005.
- [49] david gay,philips levis."he nesC language: A holistic approach to networked embedded systems",Proceeding PLDI '03 Proceedings of the ACM SIGPLAN conference on Programming language design and implementationPages 1 – 11, 2003.
- [50] Aman Kansal, Vijay , Jason," Design considerations for solar energy harvesting wireless embedded systems".Proceeding IPSN '05 Proceedings of the 4th international symposium on Information processing in sensor networks Article No. 64.
- [51] Lee, I., Leung, J. and Son, S. Handbook of realtime and embedded systems, Chapman & Hall/CRC computer & information science series, 2008.
- [52] M.Carson, D.Santay," NIST Net – A Linux-based Network Emulation Tool", in ACM SIGCOMM Computer Communications Review, Volume 33, July 2003.
- [53] Crespo, A., Ripoll, I., GonzálezHarbour,M. and Lipari, G."Operating System Support for Embedded RealTime Applications", EURASIP Journal on Embedded Systems, 2008.
- [54] Tanenbaum, A.S.; Herder, J.N.; Bos, H., "Can we make operating systems reliable and secure?," Computer , vol.39, no.5, pp.44,51, May 2006.
- [55] Zave, P., "An Operational Approach to Requirements Specification for Embedded Systems," Software Engineering, IEEE Transactions on , vol.SE-8, no.3, pp.250,269, May 1982.
- [56] Bunse, C.; Gross, H.-G.; Peper, Christian, "Applying a Model-based Approach for Embedded System Development," Software Engineering and Advanced Applications, 2007. 33rd EUROMICRO Conference on , vol., no., pp.121,128, 28-31 Aug. 2007.
- [57] Ebert, C.; Salecker, Jürgen, "Guest Editors' Introduction: Embedded Software Technologies and Trends," Software, IEEE , vol.26, no.3, pp.14,18, May-June 2009.
- [58] Jørgen Bøegh, "A New Standard for Quality Requirements", 2008.
- [59] .nancy G."Software safety in embedded computer systems", Communications of the ACM , Volume 34 Issue 2, Feb. 1991.
- [60] M. Masmano, I. Ripoll, and A. Crespo," XtratuM: a Hypervisor for Safety Critical Embedded Systems", 11th Real-Time Linux Workshop. Dresden. Germany. 2009.
- [61] J.P.Blanquart, E.Armengaud, P. Baufreton, Q.Bourrouilh, J. Machrouh," a multi-domain platform of safety process methods and tools for critical embedded systems", France, 2012.
- [62] S.Ravi, P. Kochar," Security in Embedded Systems:Design Challenges", journal ACM

- Transactions on Embedded Computing Systems, Volume 3 Issue 3, August 2004.
- [63] p. kochar, L. Ruby, G. McGraw, "Security as a New Dimension in Embedded System Design", Proceedings of the 41st annual Design Automation Conference. Pages 753-760, 2004.
- [64] M. A. Jan, P. Nanda, and X. He. 2013. "Energy Evaluation Model for an Improved Centralized Clustering Hierarchical Algorithm in WSN", in Wired/Wireless Internet Communication, Lecture Notes in Computer Science, pp. 154–167, Springer, Berlin, Germany.
- [65] M. A. Jan, P. Nanda, X. He and R. P. Liu. 2013. "Enhancing lifetime and quality of data in cluster-based hierarchical routing protocol for wireless sensor network", 2013 IEEE International Conference on High Performance Computing and Communications & 2013 IEEE International Conference on Embedded and Ubiquitous Computing (HPCC & EUC), pp. 1400-1407.
- [66] F. Khan, K. Nakagawa. 2012. "Performance Improvement in Cognitive Radio Sensor Networks" in the IEICE Japan.
- [67] F. Khan, K. Nakagawa. 2013. "Comparative Study of Spectrum Sensing Techniques in Cognitive Radio Networks" in World Congress on Computer and Information Technology, pp.1-8
- [68] M. A. Jan, P. Nanda, X. He and R. P. Liu. 2014. "PASCCC: Priority-based application-specific congestion control clustering protocol," Computer Networks, vol. 74, pp. 92-102.
- [69] Mian Ahmad Jan and Muhammad Khan. 2013. A Survey of Cluster-based Hierarchical Routing Protocols, IRACST–International Journal of Computer Networks and Wireless Communications (IJCNWC), Vol.3, pp.138-143.
- [70] Mian Ahmad Jan and Muhammad Khan. 2013. Denial of Service Attacks and Their Countermeasures in WSN, IRACST–International Journal of Computer Networks and Wireless Communications (IJCNWC), vol. 3, April 2013.
- [71] M. A. Jan, P. Nanda, X. He and R. P. Liu. 2015. "A Sybil Attack Detection Scheme for a Centralized Clustering-based Hierarchical Network," in Trustcom/BigDataSE/ISPA, Vol.1, PP-318-325, IEEE.
- [72] M. A. Jan, P. Nanda, X. He, Z. Tan and R. P. Liu. 2014. "A robust authentication scheme for observing resources in the internet of things environment" in 13th International Conference on Trust, Security and Privacy in Computing and Communications (TrustCom), pp. 205-211, IEEE.
- [73] F. Khan, S.A. Kamal, F. Arif, "Fairness Improvement in long-chain Multi-hop Wireless Ad hoc Networks" in IEEE ICCVE 2013, Las Vegas, USA 2-6 December, 2013
- [74] Tao Xie, X. Qin, "Improving security for periodic tasks in embedded systems through scheduling", ACM Transactions on Embedded Computing Systems, Volume 6 Issue 3, July 2007.
- [75] Ali, H., Saeed, A., Jan, S.R.U., Khan, A.U., & Khawaja, A. 2012. "Internet Connectivity using Vehicular Ad-Hoc Networks"
- [76] Ali, R., Ali, H., Salman & Iqbal, S. 2014. "A Novel Survey on: Mobility Based Routing in Vehicular Ad-Hoc Networks (Vanets)", Journal of Applied Environmental and Biological Sciences, pp. 487.
- [77] Mian Ahmad Jan, "Energy-efficient routing and secure communication in wireless sensor networks" PhD Thesis, 2016. <http://hdl.handle.net/10453/43497>
- [78] F. Khan 2012. "Secure communication and routing architecture in wireless sensor networks" in IEEE 3rd Global Conference Consumer Electronics (GCCE), pp 647-650
- [79] K. Nakagawa F. Khan, F. Bashir. 2012. "Dual Head Clustering Scheme in Wireless Sensor Networks" International Conference on Emerging Technologies (ICET), pp. 1-5.
- [80] M. A. Jan, P. Nanda, X. He and R. P. Liu. 2016. A Lightweight Mutual Authentication Scheme for IoT Objects, IEEE Transactions on Dependable and Secure Computing (TDSC), "Submitted".
- [81] M. A. Jan, P. Nanda, X. He and R. P. Liu. 2016. A Sybil Attack Detection Scheme for a Forest Wildfire Monitoring Application, Elsevier Future Generation Computer Systems (FGCS), "Submitted".