Power Management for Portable Devices by using Clutter Based Information

Muhammad. A, Mazliham M.S, Shahrulniza. M

Universiti Kuala Lumpur, Kuala Lumpur, Malaysia

Summary
Power management of portable devices is one of the major issues in the field of wireless communication. As the battery power is limited in portable devices, therefore it is required to manage the battery power in a way that it last longer. This research paper is focusing on the power management on the location estimation based history. The derived algorithm is divided into two parts; first: while the device is located in a single terrain only and secondly: when the device is falling at the intersection of two or more terrains. Location of the handheld device is used as a parameter for cluster calculation. At first the location estimation is done by triangulation method, an algorithm is derived which is getting information from Google earth about the terrain. Based on that knowledge by considering the Signal to Noise Ratio (SNR) and the phenomenon of reflection, diffraction and scattering it is decided that how much power will be required by the portable device to communicate with the tower. Calculation of the location is based on the Available Signal Strength (ASS) and the Receive Signal Strength (RSS). In this research, we are considering GSM architecture and the cell phone is operating as a portable device. In the last part of the algorithm, while the device is not participating in the communication it is directed to change its state from the active mode to a park mode, so the device will save the battery power. Proposed technique falls in the Dynamic Power Management (DPM) category as it is dealing with the battery power during run time.
Key words:
SNR, DPM, Clutters, Tx, Rx

1. Introduction

Number of handheld devices is increasing every year rapidly, especially the sale of cell phones in year 2007 crossed over one billion [1]. But the portable devices have limited battery power that is why it is required to manage it properly. Many researchers worked and are still working to introduce efficient way for the consumption of the battery power by using the Static Power Management (SPM) and DBP techniques. But on the other hand vendors are introducing portable devices with such a high computational power, like PDA's Multimedia Phones etc, which require more energy to go with that computational power. In this research paper we focus on GSM architecture for the power management (which may be applicable for other wireless environments like Wireless LAN etc) by using the DPM technique. We are considering the location/terrain as one of the parameter for power management, as Radio Frequencies (RF) behaves differently in different clutters/terrains [2] that is why the derived algorithm is taking terrain information from the Google earth map by providing the location information of cell phone. Location estimation is done by using the triangulation method with the parameters ASS and RSS. While the device is not in communication its information will be deleted from the database and the device will change its state from the active mode to park mode.

It is also possible that the portable device is located at the intersection of two or more terrains. As we have eight different terrains [2] and seven type of losses in RF communication that become the 128 possible subsets, which contain the information about the combination of different terrains. Second part of algorithm is dealing with the above problem.

In this research we are calculating the losses (the difference between the Tx and the Rx) by using the location of a device and the terrain information. Based on this information, decision is taken that how much signal strength (Rx) is lost and how much power (P) will be required by the portable device to stay in communication with strong signals with the sender device.

This paper is divided in to 8 sections. In section 2 characteristics of radio frequencies will be discussed. Section 3 will explain the Clutters/Terrains type. In section 4 we explain different power management techniques. Section 5 is dedicated to literature survey and discussion review. Section 6 is identifying the problem, and in section 7 we proposed an algorithm for the power management for portable devices. Which is based on the location estimation, therefore this section is divided into two phases; the location estimation and the power management. Results are discussed at the end of this section. Finally conclusion and the future directions are added in last section.

2. Characteristics of Radio Frequencies

RF behavior can be categorized as [3, 5].

Manuscript received April 5, 2009
Manuscript revised April 20, 2009

- Reflection
- Refraction
- Diffraction
- Scattering
- Absorption

Transmitter transmits (Tx) and the receiver receive (Rx). Unit used for Tx and the Rx power is dBm [4]. Relation between the dBm and the Watt is [5]

1mW = 0 dBm

When Rx passes from different terrain, mention above behavior applies on them and the Rx value differs from the Tx value [2]; which is known as loss, and can be calculated in dBm. Because of losses the gain reduces and the receiver is not able to hear the voice (signal) clearly. To avoid such a problem we require extra power so the receiver device will be able to receive the Rx properly.

3. Clutters in GSM Architecture

As the GSM architecture is the part of RF for communication, the characteristic of the radio frequencies also applies on it when the signal passes from different terrains. Based on the terrain, clutters in the GSM architecture can be defined as [2]

- Low Density Urban
- Village/Low Density Vegetation
- Medium Density Vegetation
- High Density Vegetation
- Agriculture
- Open/Quasi Open Area
- Water Bodies
- River, Sea

As Rx passes in different terrain its Rx value changes and losses in dBm increases [2]. Every clutter type has different losses such as if the device receives signals near river or sea losses will be much more compared to agriculture region.

4. Power Management Techniques

Power management (PM) techniques can be broadly divided in to two categories [6]. Static Power Management (SPM) and the Dynamic Power Management (DPM). This section is briefly discussing the both of the power management techniques in the light of the previous research.

4.1 Static Power management

SPM techniques are applied at the design time [6]. It is actually the event driven scenario. At the design time it is decided that how much energy will be required by the Central Processing Unit (CPU) and how much energy is required for system components.

4.2 Dynamic Power management

DPM techniques are applied during the run time when the system is serving the light load work or not processing [6]. DPM can be implemented in different ways. Like Dynamic Voltage Scaling (DVS) technique which decreases the processor supply voltage at the run time as a technique of power management. [7-10]. DPM can also be applied to turnoff the unused devices [11-12], or unused nodes in sensor network server clusters [13]. This research is focused to develop the technique for energy saving during runtime i.e. DPM.

5. Relevant Work

System level dynamic power management [14] saving the battery life by sending the idle components of the system in the low power state. Authors used the concept that if any component or even the device is not participating in the communication then send the device in to low power state, where device will be able to receive data as it is moved in to listen mode.

State transitions [15] are controlled by the commands runs by a Power Manager (PM) that first checks the workload of the system and on that bases decide how much power will be required for the transition.

In [16] authors implement power management at the physical and the Medium Access layer (MAC) layer level. In this architecture the central access point sends a beacon every 100 ms with the Traffic Indication Map (TIM). Every card that wants to communicate needs to actively listen the beacon to get synchronize with the access point and the TIM to check out if any data is coming for it. If any device doesn't wants to participate in transmission and reception, so it can switch into less power mode until the next beacon arrive.

Technique proposed by Tajana Simunic et al [17] works in two states, either to leave the device in the idle mode or completely shut it down. If it is left idle, then the device waits for the next transition, if it arrives then the device turn back in to active mode. If the device is in turnoff or in a sleep state then the system starts the transition between the idle and the off state. If during transition a request arrives then the device will be shifted to active state otherwise after the completion of the current transition the device will remain in off state until the next transition.

DVS proposed by Amith Sinha et al [18], which is the enhanced version of DPM. In this paper authors suggested that DPM is a good technique for saving the battery power if the device is not participating in processing, however the sleep state transitioning has overhead as well, because of storing processor state and turning off the power. Authors also pointed out after receiving the wakeup call it took finite time for the processor to wakeup. They proposed OS directed power management technique to improve the efficiency but their work focused only sensor nodes may be this technique work better with other portable devices. The proposed technique by authors "DVS" is an effective technique for reducing CPU energy, by simply reducing the operating frequency during periods of less activities will result in linear decrease in power consumption.

Robin Kravets et al [19] introduce a transport layer level protocol which is capable of significantly reducing the power usage of the communication device. Their protocol manages and queue data for future delivering when the device is shutdown or in a sleep state, it also decides when to restart the device. They implement their protocol by using IEEE 802.11 standard and claim for up to 83% saving of power consumed by the device while it is not in communication.

IEEE 802.11 standard [20] provides a Power Saving Mode (PSM) that periodically disable the network interface during the periods of no activity in order to safe the battery power. But PSM does not safe the energy power if the device is not participating in communication.

Self Tuning Power management (STPM) proposed by M. Anand et al [21] is implemented as a Linux kernel module which runs on both handhelds and the laptops. They proposed that different power management techniques are required at different level. Their STPM approach adapts the characteristics of the network interface, mobile computer and the applications and decides for the appropriate power management technique. STMP reduces consumption power of device at different level of application like distributed file system, streaming audio and thin client remote X display.

Delft Taxonomy [22] provides significant progress towards the power management solutions. Author claims that it helps to identify mature solutions such as time-out-based policies and emerging solutions such as cooperative power management.

Perfd framework by J.A. Pouwelse et al [22] describes that the traditional power management solutions use a single monolithic power management policy. The distributed power management policies with in the Perfd cooperate to find the most power efficient operation mode. The scheduler used in Perfd enhances both context awareness and information access. This enables power efficiency gains. Author claims that his model also explicit and postpones some decisions that have a high impact on power consumption to execution time, where more information is available. Another idea introduce in the Perfd is the use of performance models at the execution time as a means to make predictions and enable proactive behavior. Author claims that the power consumption will significantly improve with the implementation of Perfd.

Wake-on-wireless by Eugene Shih et al [23], authors introduce a second low power channel, which is used to shut down the rest of the system, while not participating in communication to reduce the idle power. They suggest that the out-of-band control information can be sent to maintain connectivity and wakeup the UCom device when necessary. As it sends the device in a sleep mode the battery power can be saved.

5.1 Discussion review

As mentioned in the literature survey, researchers introduce different static and the dynamic power management techniques for saving the energy of the handheld devices. But none of the researcher considered the terrain based knowledge. Terrain factor drastically changes the RF which increases the SNR, and because of this Rx value differs significantly from the Tx value which may result the lost of communication. Moreover by using the terrain information we can safe the battery power as the handheld devices consume battery power for a specific communication, which may not be required for that communication as the location of a device is in the area where the losses are low. Current research is catering the same idea for the decision of the power utilization for the portable devices.

6. Problem Statement

None of the researcher considered clutters and their impact on RF to manage or minimize the energy consumption. As when the portable devices start communication in the terrain where losses are more they start communicating with maximum power or the device lost the signal strength [2].

7. Proposed Architecture

Proposed architecture is divided in to two phases. Phase I is calculating the location of a mobile node by using the Receive Signal Strength (RSS) and Actual Signal Strength (ASS) values. For more precision it is repeated multiple times and then by using the average method calculates the location. In phase II based on the location of mobile node terrain/clutter information is taken. Based on clutter information the decision of power is taken by using the algorithm.

7.1 Phase I: Location Estimation

Our assumption is based on that the cell phone is getting signals from 3 BTS (Base Transceiver Station) in that condition 3 triangles will be constructed i.e. ΔABM, ΔACM and ΔBCM as shown in the Fig. 1

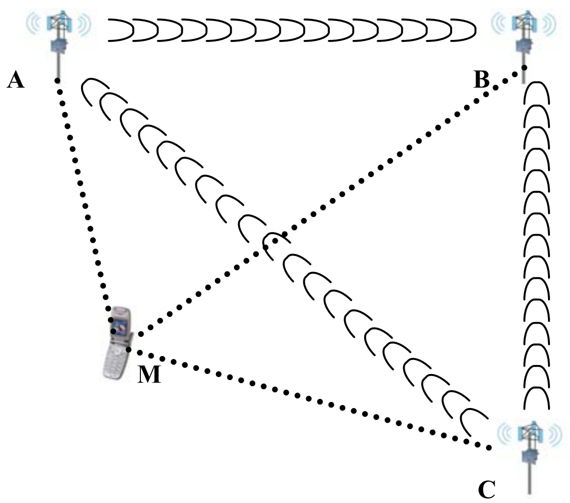

Fig. 1: The mobile node is receiving signals from 3 BTS.

By using the ASS and the RSS the distance between point AB, AM and AC is calculated.

$$D_{(AB)t0} = \frac{ASS_{(A)t0} + ASS_{(B)t0}}{2} - \frac{RSS_{(A)t0} + RSS_{(B)t0}}{2} \quad (1)$$

$$D_{(AM)t0} = ASS_{(A)t0} - RSS_{(M)t0} \quad (2)$$

$$D_{(BM)t0} = ASS_{(B)t0} - RSS_{(M)t0} \quad (3)$$

where

ASS is Actual Signal Strength at A and B at t0
RSS is Receive Signal Strength from A, B and M at time t0.
$D_{(AB)}$ is distance between point A and B.
$D_{(AM)}$ is distance between point A and M
$D_{(BM)}$ is distance between point B and M

As the location of points A, B and C are known and now also the distance between A, B and M is calculated, so by using the simple trigonometry formula angles α and β are calculated.

$$\cos\alpha = \frac{\{D_{(AM)t0}\}^2 + \{D_{(AB)t0}\}^2 - \{D_{(BM)t0}\}^2}{2\, D_{(AM)t0}\, D_{(AB)t0}} \quad (4)$$

By using basic trigonometric *formula for angle calculation with three known sides,*
$\cos\alpha = (b^2 + c^2 - a^2) / 2bc$

$$\cos\beta = \frac{\quad}{2\, D_{(BM)t0}\, D_{(AB)t0}} \quad (5)$$

By using the distance between AB AM and BM and the angles α and β we plot a triangle to estimate the location of M (Loc M) at time t0 by using ΔABM.

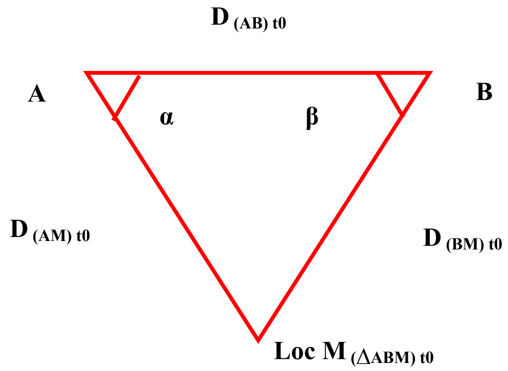

Fig. 2: Mapping of M by using distances and angles

Similarly by using triangles ΔACM and ΔBCM two other

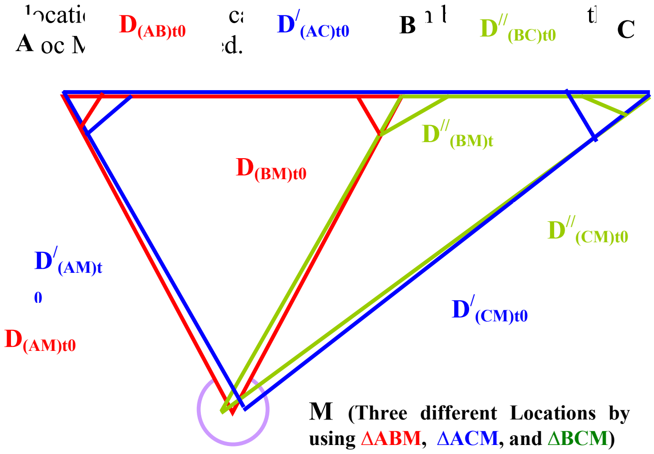

Fig. 3: Location estimation of Mobile by using three triangles, where D is the distance calculated by ΔABM, D/ is calculated by ΔACM, and D// is calculated ΔBCM.

$$Loc\ M_{to} = \frac{Loc\ M_{(\Delta ABM)t0} + Loc\ M_{(\Delta ACM)t0} + Loc\ M_{(\Delta BCM)t0}}{3} \quad (6)$$

For precession we calculate the location of cell phone at t_1, $t_2 \ldots t_n$. and average them.

$$Loc\ M = \frac{\sum_{n=0}^{n} Loc\ M_{tn}}{n} \quad (7)$$

7.2 Phase II: Power Management Algorithm (PMA).

Based on the location of cell phone terrain, power consumption decision is made. Let's assume P is the power used by the cell phone with good quality signal strength. Following is the flow which explains the step by step procedure of the location estimation by using location estimation parameters and then the power decision based on clutters decision box.

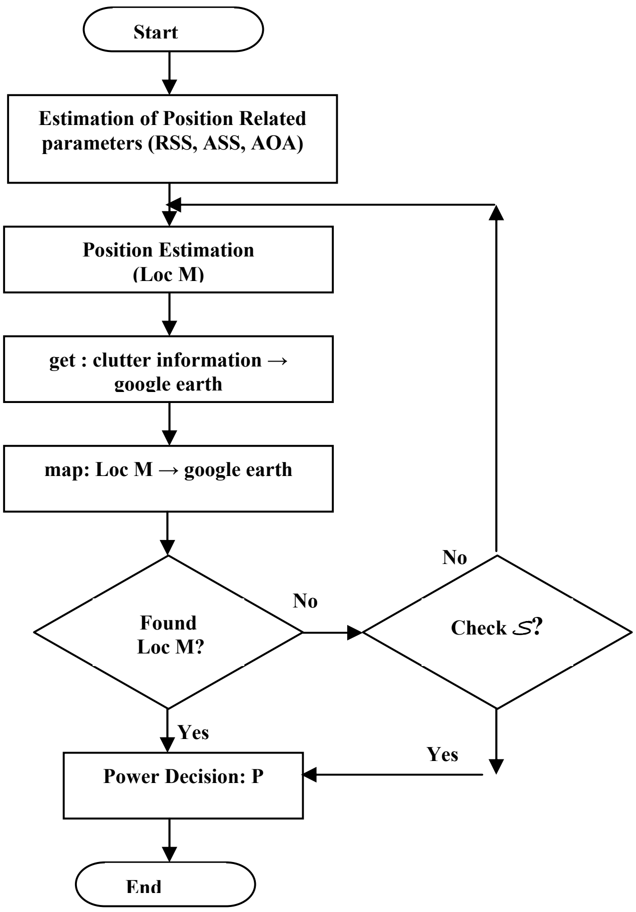

Fig 4: Flow of the location estimation and the power management decision.

Following algorithm is derived for location based power management. As shown in flow diagram there are two parts of algorithm first part of algorithm will be executed if the location of the portable device is exactly in on terrain/clutter.

```
get : google earth
 if Loc M: known
input : Loc M → google earth
        map: Loc M ∈ google earth
        if clutter type∈ AG
                input power: P
        else if clutter type∈ LD
                input power: P+ |P*0.01|
        else if clutter type∈ MD
                input power: P+ |P*0.02|
        else if clutter type∈ HD
                input power: P+ |P*0.04|
        else if clutter type∈ OA
                input power: P+ |P*0.05|
        else if clutter type∈ WB
                input power: P+ |P*0.10|
        else if clutter type ∈ RS
                input power: P+ |P*0.15|
.
.
.
        else P
 else
        input power: P*0.01
```

(Last instruction is used to send the device in listening or park mode, if no beacon receives from the tower. At this time device is using minimal battery power.)

where

P is power required for communication
AG is Agriculture
LD is Village/Low Density Vegetation
MD is Low Density Urban or Medium Density Vegetation
HD is High Density Vegetation
OA is Open/Quasi Open Area
WB is Water Bodies
RS is River and Sea

As the losses of Lowe Density Urban (LDU) and the Medium Density Urban (MDU) are the same therefore it is categorized as MD

In this framework we are trying to optimize the power management if the node is falling in the combination of clutters other then seven major clutters, through the identification of the nodes automatic location. As we consider the hypothesis, where node is automatically detected exactly in a single clutter. By following the same idea we propose in the second part of algorithm to consider the possible combinations of clutters. As we consider 7 possible clutters. We initiate it here with $\mathcal{S}$ which is equal to 2^{θ}. where θ is

$$\theta = \{AG, LD, MD, HD, OA, WB, RS\}$$

and

$$\mathcal{S} = 2^{\theta} \tag{8}$$

```
.
.
.
if clutter type ∈ S ∩ RS ≠ ∅
                    input power: P+ |P*0.15|
else if clutter type ∈ S ∩ WB ≠ ∅
                    S ∩ RS = ∅
                    input power: P+ |P*0.10|
 else if clutter type ∈ S ∩ OA ≠ ∅
                    S ∩ RS = ∅;
                    S ∩ WB= ∅
                    input power: P+ |P*0.05|
else if clutter type ∈ S ∩ HD ≠ ∅
                    S ∩ RS = ∅;
                    S ∩ WB = ∅;
                    S ∩ OA = ∅
                    input power: P+ |P*0.04|
else if clutter type ∈ S ∩ MD≠ ∅
                    S ∩ RS =∅;
                    S ∩ WB =∅;
                    S ∩ OA =∅;
                    S ∩ HD =∅
                    input power: P+ |P*0.02|
else
          input power: P+ |P*0.01|
.
.
.
```

As in RS most of the Rx loss which is up to 15% that is why if the location is falling in RS with the combination of others so it will be treated as RS power loss. WB comes after it, if the location of M is falling in the combination of clutters other than RS then it will follow the rule of WB.

7.3 Results and Discussion

In this section we will discuss about the simulation results of actual data and its comparison after the implementation of Power Management Algorithm (PMA). As discussed before that the signal lost it strength because of the clutter environment impact on it [2]. Because of the impairments face by the mobile node and to remain in communication it start approaching its maximum power. As a result mobile node lost its battery power early, if it is used from clutters with high losses/ impairments. Fig. 5 is demonstrating the same power utilization scenario. Initially the node is in park mode and it is using only 0.1mW of the battery power. But when the node gets the signals from clutter type "AG" it start communication with 5mW battery consumption as there are minimal losses in AG terrain. But when the mobile node communicates to the tower from other clutter types like "LD, MD, HD, OA, WB and RS", because of high impairments it is approaching its maximum battery power which is 10mW, to remain in communication. Simulation results of Fig. 5 showing the same. Although impairments at LD, MD, HD and OA are low even then the mobile node is using maximum battery power.

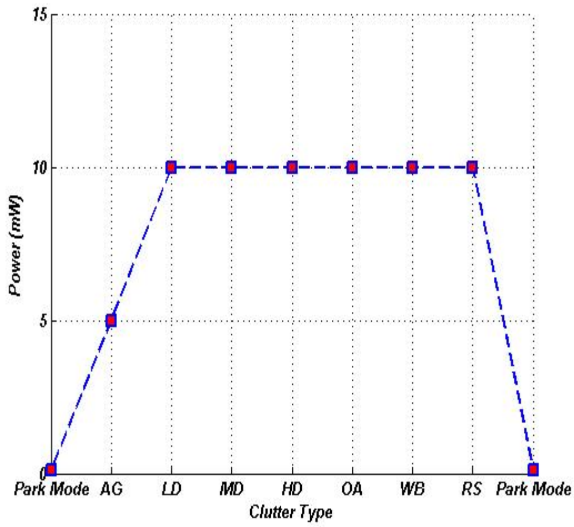

Fig 5: Power utilization of mobile node.

The PMA is introduced to cater the above problem as different clutters have different impairment/losses like High density Urban (HD) has losses of 4dBm where as river/Sea (RS) got maximum losses of 15dBm. In the first part of algorithm it is gathering the clutter information from google earth by using the location of mobile node. Based on the location, the decision of the power management is made by the PMA. As shown in Fig. 6, initially the node is in a park mode and utilizing only 0.1mW of battery power. When the node gets the signals from AG clutter type it start communicate with 5mW battery power, because of the minimal losses in AG. In LD losses are more which is 1dBm, therefore the mobile node require more power to remain in communication with good quality signals. As mention on line no 8 of PMA input power required is

input power: P+ |P*0.01|

which is 5.05mW instead of 10mW used by the mobile node without the implementation of PMA as mention in Fig. 5. Similarly whenever the impairments will increased the power will increased correspondingly as shown in Fig. 6. Results shows, with the implementation of PMA the power utilization by the mobile node is significantly saved, which is up to 40%.

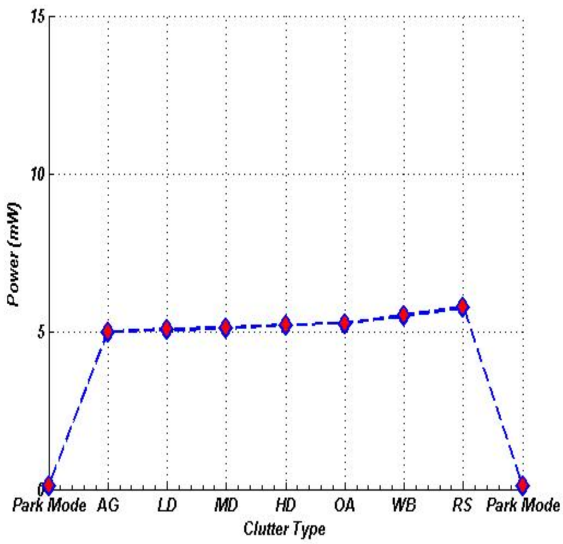

Fig 6: Power utilization With PMA implementation

The second part of the PMA is dealing with the overlapping conditions of the clutters. Finally the line no. 35 of the algorithm is sending the device in a park mode again, immediately after the termination of the call.

8. Conclusion and Future Directions

This research falls under the DPM, as decision of the power management is taken at runtime by using the location of mobile node as a parameter for the clutter information and based of this information the power management decision is taken. If the mobile node is falling in the area which is the combination of two or more clutters, then the input power decision will be based on the high impairments clutter. Suppose the mobile node is falling at the intersection of AG with the losses of 0dBm, OA with the losses of 5dBm and the RS with the losses of 15dBm, then the input power decision will be based on RS.

input power: P+ |P*0.15|

As shown in line no. 22 of the algorithm. This part of algorithm will be invoked only if the mobile node location is falling in the overlapping area of clutters with different impairment values.

In future instead of depending on the coordinates of google map, image processing techniques can be applied for the translation and calculation of clutters by using the real-time pictures and graphs especially for the calculation of $\leq$.

Acknowledgement

We would like to express our special thanks and gratitude to Dr. Mohd Amir Bin Abas the Project Director and the Director Centre for Research and Postgraduate Studies University of Kuala Lumpur and his team for their support, also we are thankful to Mr. Girard Mathieu, Ms Jawahir Che Mustafa and Mr. Azmin who share their ideas time by time with us otherwise it would have been difficult for us to complete this research in time.

References

[1] http://www.guardian.co.uk/world/2008/feb /27/nokia .mobilephones

[2] P.K.Dalela, M.V.S.N Prasad, A.Mohan. A New Method of Realistic GSM Network planning for Rural Indian Terrains, IJCSNS International Journal of Computer Science and Network Security, VOL.8 No.8, August 2008.

[3] Wireless and Mobile Communication 2nd Edition, by William Stalling.

[4] **http://onno.vlsm.org/onno/the-guide/wifi/**

[5] Lecture notes on RF fundamentals Universitas Bina Darma http://images.ilmanzuhriyadi.

[6] Wissam Chedid and Chansu Yu. Survey on Power Management Techniques for Energy Efficient Computer Systems *Proceedings of the Second Workshop on Power Aware Computing Systems*,Feb 2002.

[7] M.Weiser, B.Welch, A.Demers and S.Shenker, “Scheduling for Reduced CPU Energy”, *Usenix Association*, Nov. 1994.

[8] K.Govil, E.Chan and H.Wasserman, “Comparing Algorithms for Dynamic Speed-Setting of a Low-Power CPU”, *MobiCom* 1995.

[9] G.Quan and X.Hu, “Energy Efficient Fixed-Priority Scheduling for Real-Time Systems on Variable Voltage Processors”, *Design Automation Conference*, 2001.

[10] D.Son, C.Yu and H.Kim, “Dynamic Voltage Scaling on MPEG Decoding”, *International Conference on Parallel and Distributed Systems (ICPADS)*, 2001.

[11] Y.Lu and G.De Micheli, “Comparing System-Level Power Management Policies”, *IEEE Design & Test of Computers*, March 2001, pp10-19.

[12] A.Sinha and A.Chandrakasan, “Dynamic Power Management in Wireless Sensor Networks”, *IEEE Design & Test of Computers*, March 2001, pp62-74.

[13] E.N.Elnozahy, M.Kistler and R.Rajamony, “Energy-Efficient Server Clusters*”, In Proceedings of the Second Workshop on Power Aware Computing Systems*,Feb 2002

[14] L. Benini and G. De Micheli, *Dynamic Power Management: design techniques and CAD tools,* Kluwer, 1997.

[15] Intel, Microsoft and Toshiba, "Advanced Configuration and Power Interface specification", available at http://www.intel.com/ial/powermgm /specs. html, 1996.

[16] The Editors of IEEE 802.11, *IEEE PSO2.11D5.0 Draft Standard for Wireless LAN,* July, 1996.

[17] Tajana Simunic , Luca Benini , Peter Glynn ,Giovanni De Micheli Dynamic power management for portable systems International Conference on Mobile Computing and Networking Proceedings of the 6th annual international conference on Mobile computing and networking http://portal.acm.org/ toc.cfm?id=345910&type=proceeding&coll=GUIDE &dl=GUIDE&CFID=29072218&CFTOKEN=63626 588 Boston, Massachusetts, page(s): 11 - 19 , 2000 ISBN:1-58113-197-6

[18] Sinha, A. Chandrakasan, A, Dynamic power management in wireless sensor networks Design & Test of Computers, IEEE Mar/Apr 2001 Volume: 18, Issue: 2 page(s): 62-74 ISSN: 0740-7475

[19] Robin Kravets **,** P. Krishnan Power management techniques for mobile communication. International Conference on Mobile Computing and Networking Proceedings of the 4th annual ACM/IEEE international conference on Mobile computing and networking Dallas, Texas, United States Pages: 157 – 168, 1998 ISBN:1-58113-035-X

[20] IEEE Local and Metropolitan Area Network Standards Committee, WirelessLANMedium Access Control (MAC) and Physical Laye (PHY) Specifications, IEEE Std 802.11-1997, New York, New York (1997).

[21] Manish Anand, Edmund B. Nightingale Jason Flinn. Self-Tuning Wireless Network Power Management . Wireless Network Journal, Issue: volume 11, November 4 july2005, page (s): 451-469

[22] J.A. Pouwelse, PhD Thesis “Power Management for Portable Devices", Delft University of Technology, 20 Oct 2003

[23] E Shih, P Bahl, MJ Sinclair. Wake on wireless: an event driven energy saving strategy for battery operated devices. International Conference on Mobile Computing and Networking. Proceedings of the 8th annual international conference on Mobile computing and networking Atlanta, Georgia, USA SESSION: Energy Efficient Systems Pages: 160 – 171,2002 ISBN:1-58113-486-X