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Energy Efficient WMSN for Virtual Sensor-Based Global Information Sharing using Mobile Cloud

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Abstract— Wireless Multimedia Sensor Networks (WMSN) have recently gained the attention of the research community due to their wide range of applications and are currently being used in several applications in which Multimedia Surveillance Sensor Network and Environment monitoring are important ones. These applications need to continuously capture images in order to monitor certain events. In this paper an energy efficient mechanism Energy Efficient Sensing and Web-based Sharing (EESWS) is presented in which the target detection capability is increased by means of rotation of IP camera sensor node in WMSN as it detects any target in its Field of View (FoV), rotates until the target moves out of CS's FoV and activates the video module when either target stops or roaming around a particular position. Multimedia contents, captured by IP camera, can be viewed directly by remote user, through either making connection between IP camera and itself i.e. with mobile phones, PCs etc. or can be viewed after getting alert message from the network. The multimedia contents of target environment then can be uploaded to social networking cloud. On an average 47.13% energy efficiency is achieved in EESWS.

Index Terms—Cloud Computing, IP Camera Sensor, Mobile Cloud, Social Networking, WMSN, WSN.

1 INTRODUCTION

Wireless sensor networks (WSN) have drawn the attention of the research community in the last few years, driven by a wealth of theoretical and practical challenges [1], [2]. This growing interest can be largely attributed to new applications enabled by large-scale networks of small devices capable of harvesting information from the physical environment, performing simple processing on the extracted data and transmitting it to remote locations.

Mobile devices, wearable and wireless sensor networks have been lately used to monitor and sense real world.More recently, the availability of inexpensive hardware such as CMOS cameras and microphones that are able to ubiquitously capture multimedia content from the environment has fostered the development of WMSNs [3], [4], [5]. Wireless multimedia sensor networks offer a wider panel of applications whether for environmental, industrial or military monitoring [6]. Most recent studies in WMSN focus on increasing the network lifetime [7].Target monitoring is an important application of WMSN.

The evolution of the web in terms of the proliferation of online social networks have generated large amount of information, describing dynamic interaction among people and their surroundings in both, digital i.e. online and real worlds i.e. offline, making people-generated information to become a new type of virtual sensor. The sensor-based applications/services will utilize sensors for purposes beyond the scope of the original sensor design and deployment, creating in this way an instantiation of a Virtual Sensor Network (VSN) for serving user-specific requests. Actually VSN is an emerging form of collaborative WSN. Virtualization is the key enabler for decoupling the physical sensor deployment from the applications running on top, and is thus a significant step towards the decoupling of ownerships in the Internet of Things [8]. The amount of information available from the connected world, either belonging to virtual or to physical sources, can describe aspects of reality in a detailed manner if both sources are combined. The kind of dynamics that the integration of digital and physical worlds may generate will have an impact at different levels, involving the human-social-environmental dimensions as well as at the network organization. Social networking has become a significant aspect of many peoples' lives as they communicate with others who are members of the same social networking application. Users manage local profiles on their wireless devices which form ad-hoc networks with any other devices they encounter, exchange profile data to establish a degree of commonality or interests [9], [10].

This paper presents a mechanism Energy Efficient Sensing and Web-based Sharing (EESWS) in which WMSN, Smart phone technology and the concept of Social Networking are combined to improve target tracking capability of sensor nodes obviously in an energy efficient manner and also make this information available to the distant users, interested in gathering knowledge about remote environment where may have no people intervention. In this mechanism after detecting a target in its FoV, the IP camera sensor (CS) rotates as the target moves within the sensor field or in the area of interest till target is in its FoV and when target stays at or roaming around a particular position then the video module of camera sensor node is activated to detect the behaviour of target. Thus the detection capability of any target using the camera sensor increases. The multimedia contents, captured by CS, then can be viewed by remote users via internet and social networking sites as [11], [12]. IP camera modules are used in our proposal.

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The task of monitoring target is done in an energy efficient manner.

2 State Of The Art Review

The mobile object tracking is one of the WMSNs applications. This application consists in locating the mobile target at every step of its progression in the surveillance area [13], [14], [15]. Dynamic clustering is the most used technique in literature [16].

The authors propose a distributed solution based on node collaboration to select the optimal subset of camera sensors that participate in the target location process [17]. SensEye is the first solution that introduces the concept of heterogeneous network [18]. The authors also used the concept of heterogeneous networks but for different objectives [19]. In authors propose a low-cost new solution for tracking a mobile target called Energy Aware Object Tracking (EAOT) [7]. It consists of a distributed cooperative algorithm that runs in heterogeneous Wireless Sensor Networks composed of both scalar and multimedia sensors. The scalar sensors (SS) are equipped with a motion detector; their role is to detect the target and then activate the camera sensors (CS) through message exchanges.

The authors proposed a wireless sensor network deployment for rural and forest fire detection and verification using IP camera module [20]. The authors present a system based on a wireless sensor network for forest fire monitoring [21]. The Forest-fires Surveillance System (FFSS) has been developed to survey the mountains of South Korea [22].

The objective of FireWxNet is to determine the behaviour of fire rather than its detection [23]. Author proposed to use an anomaly detection method based on Virtual Sensors to help detect overconsumption of fuel in aircraft [24]. Author proposed Wireless healthcare monitoring system with RFID enhanced video sensor network [25]. Authors examine use of a mobile device-based social networking service as an information ground in [26]. The service allows users to proposed VENETA, a mobile social networking platform which, among other features, implements our novel friend of friend detection algorithm. Authors proposed form groups and send text and photo messages to those groups [28]. The authors an open source framework, SenseFace, which seamlessly incorporates a body sensor network(BSN),cellular network, Internet and an overlay network consisting of social networks, to pass sensed data from a mobile BSN to social networks [27].

Authors consider the camera sensors are static i.e. they can't rotate [7]. We have improved the performance of WMSN in both target detection capability and energy consumption by considering rotational motion of IP camera sensor in EESWS and we have provided remote users with the facility of receiving multimedia contents via wireless IP camera module using internet.

3 Sytem Model

3.1 Network Architecture

We have considered Multi-tier clustered architecture of WMSN here [6], [29]. In this architecture, the tier 1 consists of scalar sensors that perform simple tasks, like measuring scalar data i.e. light, temperature etc. from surrounding environment, the tier 2 consists of camera sensors that perform more complex tasks such as image capturing or object recognition [30], [31], [32]. Each tier has a central hub or gateway for data processing and communication.

3.2 Cluster Formations

In our new approach, clusters are formed statically at the time of network deployment so all the member nodes and their related leader nodes are defined before the tracking algorithm comes into play. This cluster ready infrastructure brings simplicity into target tracking and decreases the energy consumption.

3.3 Kinematic Moel of Rotational Camera

In our new proposal we have used rotational camera sensor node. In this subsection we give some definitions.

Definition 1 Each object located in the Field of Detection (FoD) of SS can be detected. FoD is represented by a circle with radius D as illustrated in figure. 1 (a).

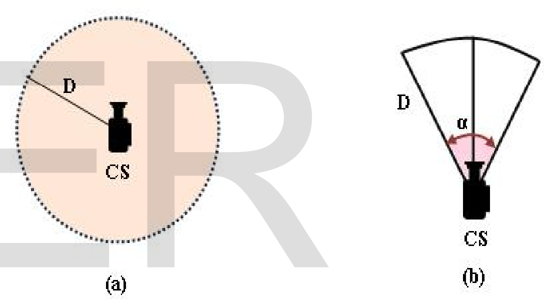

Fig. 1. (a) FoD of CS; (b) FoV of CS

Definition 2 The Camera Sensor (CS) is a wireless multimedia sensor equipped with both motion detector and camera. Each object located in CS's FoV can be visually detected. FoV is a CS's directional of view and it is assumed to be a cone with angle α and radius D as illustrated in figure. 1 (b).

3.4 Energy Moel for Packet Exchange

Heinzelman proposed a mechanism for power aware transmission in wireless networks [33]. They used a transceiver model in which the power consumed to transmit a k-bit message over a distance d is given by (1) [34].

$$E_t = k * (E_{elec} + \varepsilon_{amp} * d^{pl}) \quad (1)$$

Where E_{elec} is the energy used by the circuit per bit, ε_{amp} is the energy used by the amplifier per bit, and pl is the path loss exponent. The power consumed in receiving k bits is given by (2),

$$E_r = k * E_{elec} \quad (2)$$

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3.5 Communication Model using Wireless IP Camera Module

IP Network Cameras are designed to work in a Local Area Network (LAN) and over the Internet. Within a LAN, IP Network Cameras allow for monitoring local to the computer network to which the cameras are attached to. With additional configuration of users' computer network users can have the ability to allow for users' IP Network Camera to be monitored not only locally but remotely as well using the Internet. IP cameras send images and stream live video via digital packets across an internet protocol network such as a LAN (Local Area Network) or the Internet. This means multimedia contents of surveillance environment can be accessed remotely, via smart phones, and stored remotely giving users increased flexibility. The communication model of wireless IP camera and smart phone is depicted in figure. 2.

4 Energy Efficient Sensing And Web-Based Sharing

In this paper we present an improved performance both in target detection capability and energy consumption over EAOT proposed in [7].

Fig. 2. Communication model of wireless IP camera and mobile

The main objectives of our proposition are:

- To increase the target detection capability.
- To save the energy consumption of network.
- To enable the remote users to view the targets environmental condition, through connecting users with IP camera module and uploading multimedia contents to Social networking cloud.

In our proposed mechanism a blend of three technologies i.e. WMSN, Smart Phone and Social Networking can be seen. Here we want to improve the target tracking capacity of sensor nodes equipped with rotating IP camera than using static camera sensor nodes. But still using rotational camera we have managed the whole process of target tracking and message passing in such a way that the energy consumption of our proposed system is much less than using static camera sensors as proposed in [7]. So not only target tracking but also energy efficiency and information sharing are given same importance in our proposition EESWS.

We have considered that the target moves in a straight line as shown in Fig. 3 by red dotted arrow line. When a target enters in the area of interest then SS in the border region of clusters detects the target and predict, the target's next location after a predefined time interval, and trigger first camera sensor (CS_1) that is within their transmission range and nearest to the target's path by broadcasting DETECTION messages. The first camera sensor becomes active after target enters the area of interest when CS_1 receives at least 2 DETECTION messages that is set as threshold. Then CS_1 starts rotating horizontally as the target moves. When the target is about to move out of FoD of CS_1 then CS_1 passes a control message to the next CS (i.e. CS_2), according to the target movement path as shown in figure. 3, to activate CS_2. When the target moves out of FoD of CS_1, CS_1 goes to sleep mode. Now CS_2 rotates with the moving target. When the target is about to move out of FoD of CS_2, it activates another CS (i.e. CS_3) by passing one control message and when target moves out of FoD of CS_2, it goes to sleep mode. Any CS is activated only after receiving either " 2 DETECTION messages from SSs for any new target" or "1 DETECTION message and while waiting for another DETECTION message CS received 1 control message from another CS" or "only after receiving 1 control message from another CS". The process continues for target monitoring as shown in figure. 3.

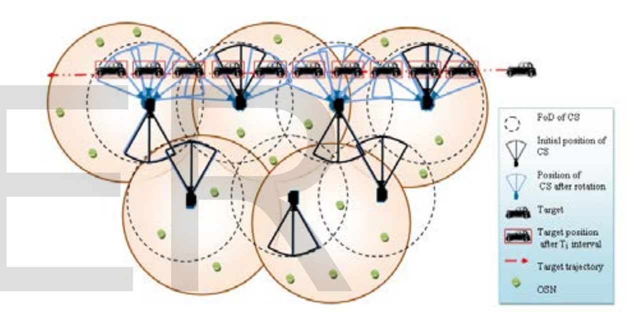

Fig. 3. An example of target monitoring with EESWS

In EESWS for monitoring target behaviour video sensor will also be activated in two cases,

- *Case 1*: If target stays at a particular position in the Area of Interest for more than a predefined amount of time then the video module of CS, within whose FOV the target belongs for that moment, will be activated to monitor target behaviour and when video module is activated the CS stops rotating.
- *Case 2*: If the target moves to and fro around a particular position then the video module of CS, within whose FOV the target frequently visits a particular position or area, will be activated. Actually what will be the target's next location after a predefined time interval is predicted on the basis of target's current position and if predicted next location matches with the previously visited position of the target then it is ferred that target is to and fro and thus the video module gets activated.

Here we use the concept of Dual Sink i.e. we have used a single static sink and multiple mobile sink. The DETECTION message is received by the Mobile Sinks within the transmis-

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sion range of those SSs. Thus after receiving DETECTION message Mobile sinks move towards the CS_1 and CS_1 sends its sensed data to only that mobile sink which sends the REPLY message first to the CS_1. Now when CS_1 passes a control message to the next CS (i.e. CS_2), according to the target movement path, to activate CS_2 then mobile sinks within its range also receive that control message and moves toward CS_2 and thus CS_2 sends data to only that Mobile sink which replies CS_2 first. The process continues till target is in Area of Interest.

In this proposition presented here, as the camera sensor rotates with moving target, the target detection capability increases than that of using fixed camera sensors.

We consider here the energy consumption for rotational motion of camera and for passing messages within the network. The energy expenditure for rotational motion of CS is calculated using the following (3).

$$E_r = 0.5 * I_d * \omega^2 \qquad (3)$$

Where, I_d = Moment of Inertia of camera module, ω = angular velocity. Thus the energy expenditure for CS_1's activation is calculated using (4).

$$E_{mc_1} = E_r + E_{act} + 2 * E_{tx} + 3 * E_{rx} \qquad (4)$$

and for activating other camera sensor nodes (CS_i for i = 1, 2, 3 … n) each time the energy consumption is calculated using (5).

$$E_{mc_{other}} = E_r + E_{act} + E_{tx} + 2 * E_{rx} \qquad (5)$$

Where, E_{act} = Activation energy of CS, E_{tx} = Energy of packet transmission, E_{rx} = Energy of packet receive.

IP camera modules are used in our proposal. The remote users can be connected to IP camera modules via downloading, software to choose the camera module to be watched, in their mobile phones or PCs. Thus the software opens a connection with desired camera and receives multimedia contents via IP camera module. The multimedia contents, received in this way, can then be uploaded to the social networking cloud as virtual sensor. The system architecture is shown in figure. 4. As the remote users receive the desired information of surveillance environment via network and social networking sites, not directly from the sensor field, a concept of virtualization of sensor network have been visualized. Remote mobile users can receive Multimedia contents of area of interest in two situations:

- *Case 1:* In Normal/No event Condition.

In normal condition when the remote users want to receive multimedia contents of surveillance environment, they simply connect their mobile phones or PCs with wireless IP camera module via software, downloaded to their smart phones or PCs and thus receive desired information of the area of interest. The received contents can be uploaded to Social networking sites i.e. twitter, orkut, facebook, myspace, YouTube etc.

- *Case 2:* In Suspicious/Event based Condition.

In case of any target detection or any kind of abnormal event occurs, then information captured by IP camera modules, are sent to the base station via GN. Then the remote users are informed about the suspicious condition by the network via sending Alert messages to smart phones or PCs, so that they can connect their devices with IP camera module to receive desired information of surveillance environment.

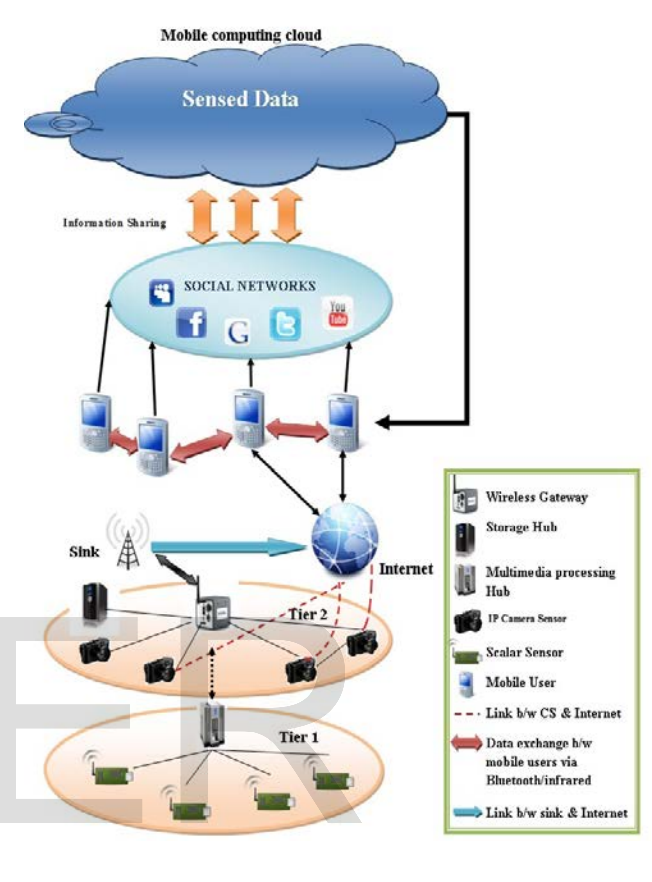

Fig. 4. System architecture of EESWS

5 Simulation Result

We have used Matlab7 simulator to simulate our proposed algorithm EESWS. We have used 1.3 Mega Pixel TOP3803 CMOS IP Camera Module interfaced with RS485 and Hi3512 camera chip. In all scenarios, all the nodes are placed in a rectangle area.

The two metrics are used to compare EESWS with EAOT: Target detection by CS and energy consumption. All the parameter value for simulation is summarized below.

5.1 Target Detection by CS

We have considered a defined target trajectory. In figure. 6, if the target is detected by CS then the phenomenon are represented by 1 otherwise 0 i.e. in case of not detection.

Our new proposed solution EESWS performs better than EAOT as shown in figure. 6. Initially in both scenario target is detected by CS. After some time span when the target moved out of detection range of fixed CS, target is not detected by fixed CS but is detected by Rotating CS either in still image mode or video mode as it rotates with the moving target.

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Again when the target comes within the detection range of fixed CS, target is detected by fixed camera. The detection line of EESWS takes constantly the value 1 because the target is always detected by rotational CSs as CSs rotate with target movement.

5.2 Energy Consumption

The energy expenditure is much less in EESWS than EAOT as shown in figure. 5. We have considered here that the target is within the area of interest throughout whole time span. As per EAOT if the target is in area of interest, DETECTION massages are broadcasted by SSs each time CS is activated and if target is within FoV of CS, CS sends LOCALIZATION Massage.

TABLE 1
SIMULATION PARAMETER FOR WMSN

Parameter	Value
Target speed (v)	1.38m/s [7]
Transmission range (d)	30 m
Depth of view (R) of CS	20 m [7]
Angle of view of CS (α)	60° [7]
Size of message (k)	64 Kb [7]
Mass of IP Camera module	0.06 Kg
Length of IP Camera module	38 mm
Width of IP Camera module	38 mm
Energy used by circuit/bit (ε_c)	50nJ/bit/m² [4]
Energy used by amplifier/bit (ε_{amp})	0.1nJ/bit/m² [4]
Path Loss (pl)	2 [4]

In EESWS, when target enters in the area of interest, to activate the first CS only, DETECTION massages are broadcasted by SSs. Multiple Mobile Sinks present within the range of SSs also receive DETECTION message but which one responds first to the CS, data gathered by CS are transmitted to that Mobile Sink only. When target is about to move out of FoD of CS then CS passes a control massage to the next CS to activate it. The Mobile Sink also receives this control message and moves towards the next CS accordingly. When the target stays or roam around a particular position then video module is activated but camera sensor stops rotating. The energy consumption of network in EESWS is calculated using (3), (4) and (5).

Spikes in line of energy consumption of EESWS, indicates that the control massage is passed between two CSs when one CS transmits control message to next CS to activate it and straight line indicates no massages are passed by CS, only energy is consumed for rotational motion of CS.

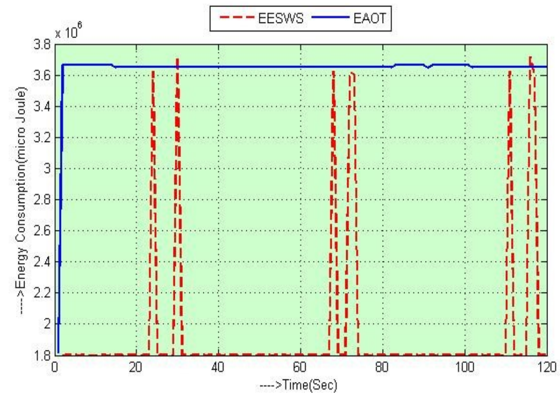

Fig. 5. Energy consumption (micro Joule) Vs Time (sec)

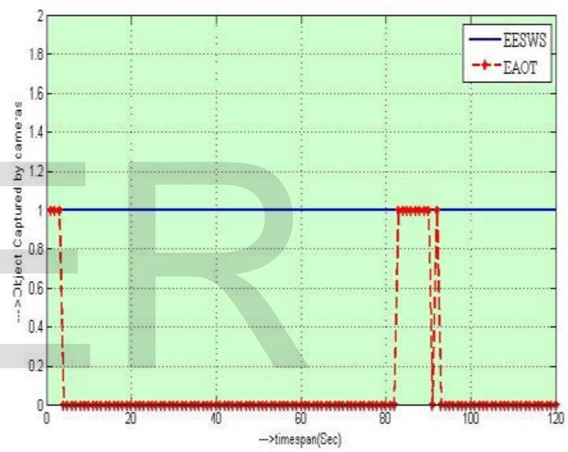

Fig. 6. Taget detection capability

5.3 Rotation of Camera Sensor Nodes

Rotation of Camera sensor nodes is shown in figure. 7. Here we have considered only 4 CSs' rotation. Initially we have considered that CS_1 is at 90º, CS_2 is at 270º, CS_3 is at again 90º and CS_4 is at again 270 º angles with positive X-axis. It can be seen from figure. 7 that first CS_1 starts rotating as the target moves and thus graph of CS_1 increases. In the mean while when target stays CS_1 stops rotating as the video mode is activated and the graph of CS_1 becomes straight line for short while. Then again CS_1 starts rotating when target moves, so the graph of CS_1 again starts increasing as its rotational angle increases with respect to positive X-axis.

Now when displacement of target is about 40 m then it exits from FOD of CS_1 and enters the FOD of CS_2. So CS_1 stops rotating and CS_2 starts and accordingly the graph of CS_1 becomes stable and that of CS_2 starts increasing. This process is followed by CS_3 and CS_4 also which is also shown in figure. 7.

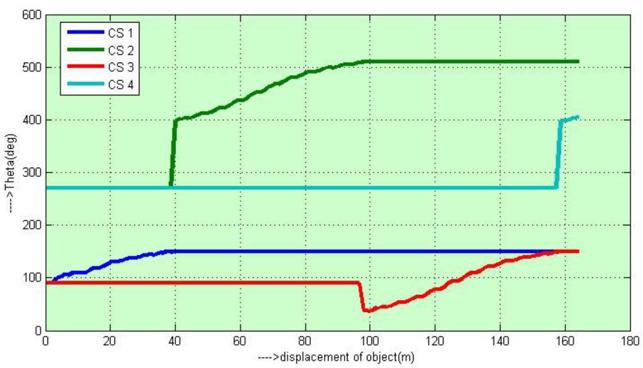

Fig. 7. Rotation of CS Vs Displacement of Target Object

6 Conclusion

Mobile devices and wireless sensor networks have been used to monitor and sense real world. Information that has been sensed in the real world has been used for a wide set of applications. The evolution of the web in terms of the proliferation of online social networks have generated large amount of information, describing dynamic interaction among people and their surroundings and made these information as a new type of virtual sensor. Thus confluent WSN, Mobile devices and Social networking is an enriched approach envisioning, addressing the challenges of Sensor Network that has been proposed in this side. EESWS is a mechanism in which IP camera sensor rotates with the moving target when the target is in the detection range of that camera sensor. Thus the detection capability of the network increases than that of using static camera sensor. As the lifetime of WMSN is one of the crucial issues, the detection mechanism is presented in an energy efficient way to save the energy consumption of WMSN. The captured multimedia contents can be globally shared by remote users via connecting their smart phones or PCs to the IP camera module and uploading those multimedia contents to the social networking cloud. On an average the energy consumption for EESWS is approximately 1.92×10^6 µJ than earlier 3.63×10^6 µJ [7] i.e. 47.13% energy efficiency is achieved in EESWS.

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