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Development of Wireless Sensor Networks (WSNs) for Water Quality Monitoring

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Abstract

Sustainable water resource management decisions are made on the support of real time water quality monitoring data at fine temporal and spatial granularities. Recently, development of wireless sensor networks (WSNs) indicates a great potential to revolutionize water quality data measurements. In this paper, based on our existing work, we report our progress to collect water parameters through utilizing STORM3 from *YSI*, a WSN from *National Instruments (NI),* and eKo Pro Environmental Monitoring System from *Memsic*. Their prototypes have been deployed in the pond at Lamar University in Beaumont, TX. Two H-377 water temperature sensor probes from *WaterLOG* have been integrated with STORM 3, the 15-minute interval water temperature data have been collected since October 1, 2015. Two sensors provided the consistent sediment temperature data for one year. To provide better hydrodynamic analysis, two sensors have been deployed at two different depths and continue to provide good data. The on-going research to develop hydrodynamic model to predict the water temperature by utilizing the data from WSNs.

INTRODUCTION

There is an urgent need to integrate state-of-the-art technology to collect necessary data and thus facilitate the development of models for water sustainability research. Enough data are essential to support validation of water quantity and quality models with a focus on prediction uncertainty. Wireless communication has become ideal candidate to enable various efficient water parameter collection technologies. The convergence of wireless technology and the Internet make it feasible to deepen our understanding of water resources and to develop models for their sustainable management. The real-time data collection could greatly help us understand of water availability, quality and dynamics.

In this paper, based on our previous research (Sun 2015), we report our progress to utilize wireless communication technology to collect real time water quality monitoring data through utilizing three representative research products, specifically, STORM3 (Storm Central) from *YSI*, a WSN from *National Instruments (NI),* and *eKo Pro* Environmental Monitoring System from *Memsic*.

These three systems adopt different hardware platforms, software design and network architecture. They have different costs and unique characteristics. To test their performance, we perform the following tasks in the pond at Lamar University in Beaumont, TX: 1.We report the water temperature data collected at two different depths in the pond at Lamar University, Beaumont, TX through STORM 3 cloud computing system. Two H377 water temperature sensor probes are deployed at different depths in the pond. The collected temperature data are transmitted to the system through STORM Central Data Collection Platform; 2. We deployed a prototype wireless sensor network based on *eKo P*ro Environmental Monitoring System from *Memsic*. We utilize *eS1101* sensor probes (eS1101) from *Memsic* to monitor the water temperature in the same pond. Collected data are transmitted in a multi-hop mesh network to the gateway, which we can access in our office.

The rest of the paper is organized as follows. We briefly present related work in Section 2. In Section 3, we present the detailed design of our system. In Section 4, we present the result of our collected dada. We conclude our paper and discuss the future work in Section 5.

RELATED WORK

We utilize the cutting-edge wireless communication based technology to help collect water data to enable water sustainability research. There have been numerous research over the past few years in this area. Broadly speaking, these research focuses on two categories: 1. Wireless communication infrastructure, they use different wireless communication technologies to transmit the collected data to a control station; 2. Third-party sensor probes. They are sensor probes used to measure a specific water parameter. Research efforts are needed to connect these sensor probes work with the adopted wireless modules.

DETAILED DESIGN

STORM 3 from YSI, WSN from NI, and eKo Pro from *Memsic* represent three of the most popular research products to apply wireless communication and sensing technologies to water research.

For the detailed introduction to wireless modules, network architecture, and sensor probes utilized in STORM3 and NI based WSN, please refer to our previous paper (Sun 2015). Here we only introduce our network design based on the eKo Pro.

The eKo Pro environmental monitoring system is an outdoor wireless environmental sensing system. The network architecture of eKo Pro Environmental Monitoring System is similar to NI based WSN. All the wireless modules may self-organize and form a wireless mesh network. We adopt eK2120 (eK2120) – the outdoor long range wireless module. Each wireless module is solar powered and alleviate the power issues faced by WSNs. It is straightforward to utilize eKo Pro to set up a multi-hop WSN. Each node could be used as a router to relay data for other nodes. Therefore, it is easy to use eKo to cover a wide area.

Each eK2120 has 4 sensor ports and can support 4 eKo compatible sensor probes. The data are measured once every 15 minutes, which meets the requirement of most applications. The radio frequency is 2.045 GHz to 2.480 GHz.

One eK2120 is deployed right outside of MAES building at Lamar University to improve reliability. One eB2100 – an eKo Base Radio is utilized to provide the connection between eKo eK2120 and the Gateway. Software eKoView is then installed on a Laptop and provides a web based browser based interface to visualize the deployed WSN. eKoView makes it convenient for end users to manage, monitor, and access data anywhere and anytime with an Internet connection. End users can also monitor the packet yield, network health, server health, etc. Figure 1 illustrates our deployed eK2120.

Figure 1: Deployment of eK2120 to monitor the pond close to John Gray Center at Lamar University, Beaumont, TX.

We use the sensor probes eS1101 – Soil Moisture and Temperature Sensors (eS1101) to monitor the water temperature. We put its temperature sensor probe under water to measure the data. Its sensor probe could measure temperature between -40C and +70C with an accuracy of +/-5%. The collected water data are transmitted in two hops to the based station outside of our office. We carefully select the locations to deploy eK2120 to make sure that there is line of sight between two eK2120 nodes.

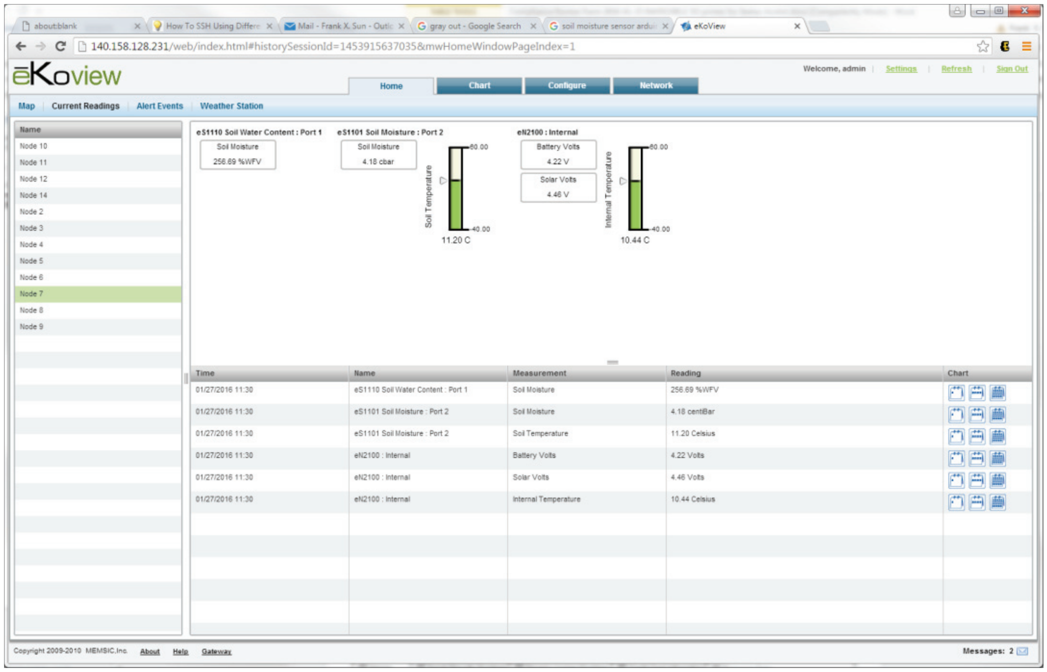

Figure 2. Snapshot of using eKoView to access the sensor data.

Figure 2 illustrates the health status (battery volts and solar volts) of a particular node and its current sensor reading through the usage of eKoView. This solution could help end users diagnose whether a node is working properly.

Figure 3 illustrates our deployed eK2120 around Lamar campus. As we can see, Node 7 is deployed to monitor the John Gray Center pond temperature. Node 11 and node 3 are utilized as relay nodes to relay data packets to the base 0. We choose the location of node 3 and node 11 because there are multiple buildings between node 7 and base 0. A line of sight between two neighboring nodes in order to improve reliability.

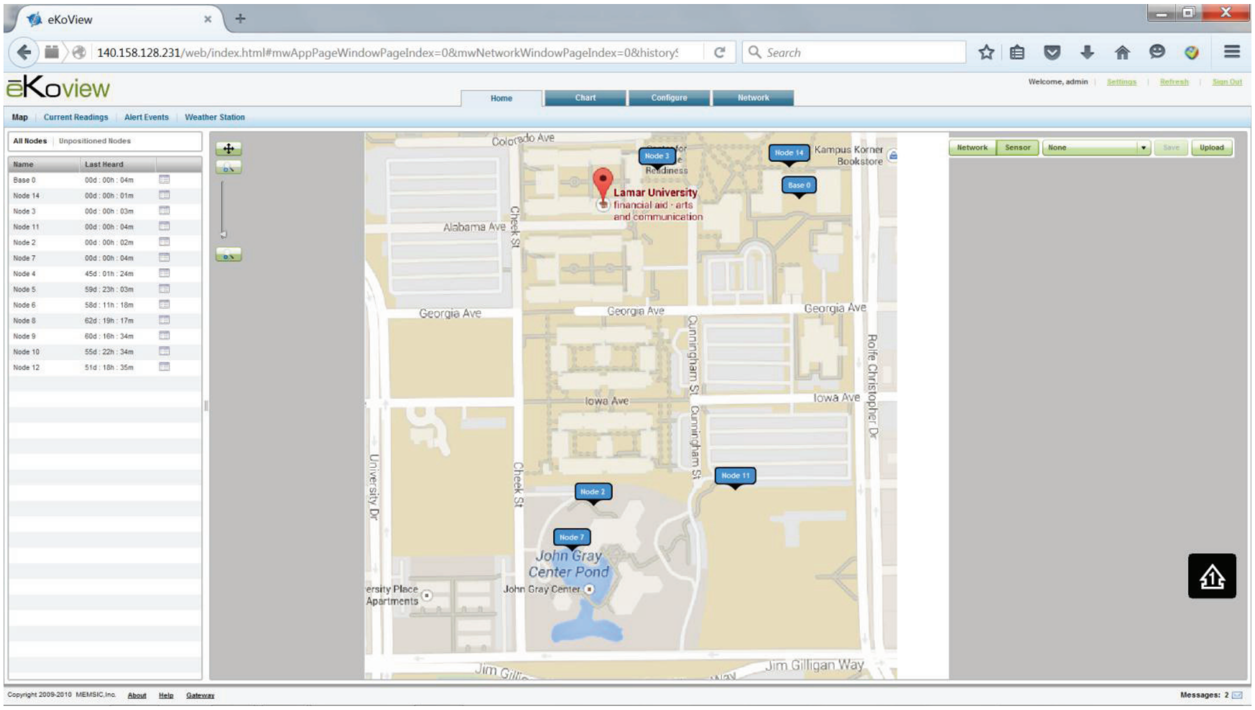

Figure 3. Deployed eK2120 Wireless Modules in Lamar Campus.

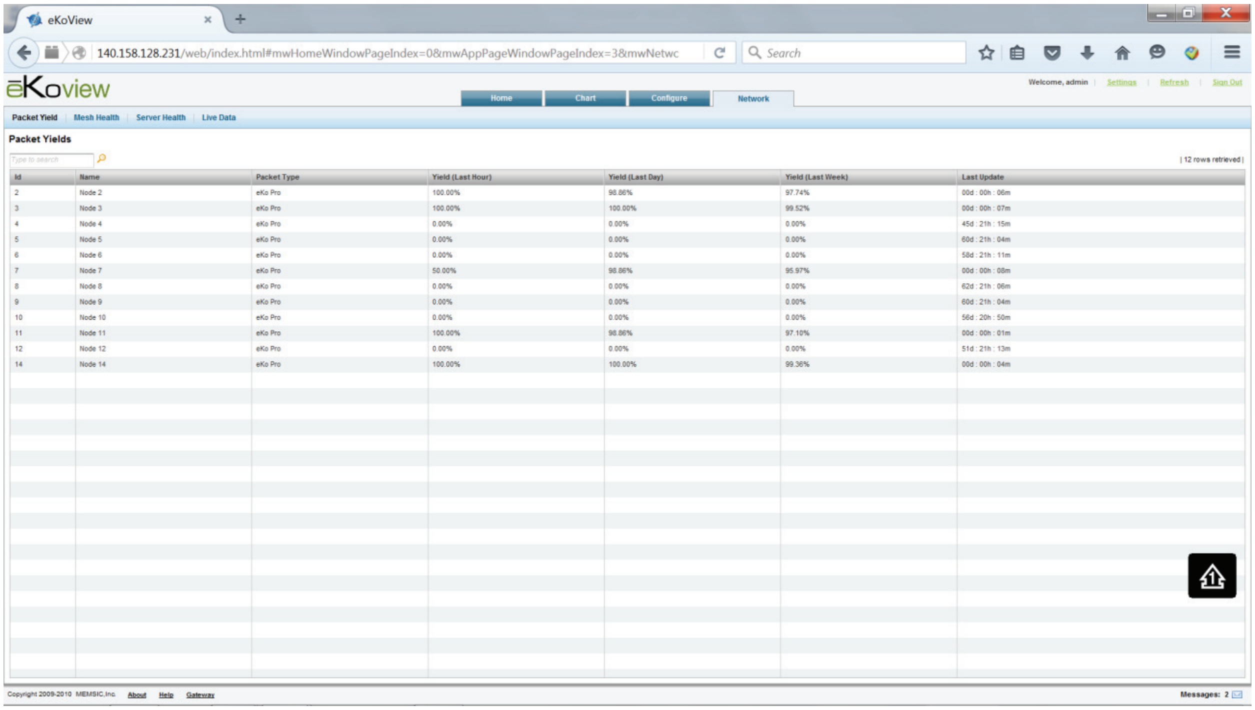

Figure 4: Network Health Status Monitoring.

Through eKoView, Figure 4 illustrates the health status of each node in terms of Yield in the Last Hour, Last day and Last week. The monitoring of these data could provide insight of the health status of these nodes.

Comparisons among STORM 3, NI WSN and eKo Pro

We present our Comparisons among STORM 3, NI WSN and eKo Pro based on our deployment experience of these three systems.

WSNs based on both *NI* and *Memsic* are popular in various research disciplines. The wireless communication in NI WSN based on WSN3212 and WSN 3216 is very reliable. NI also provides a list of documentations to make it easier to connect various sensor probes (such as Dissolved Oxygen Probe DO6400 from *Sensorex*, pH Value Probe S8000 pH Electrode from *Sensorex* etc.) to its wireless modules. However, these third-party sensor probes need much efforts to calibrate and regularly maintain. It is also nontrivial to configure WSN from NI as a multi-hop network, which limits its applications. Extra devices are needed in the infrastructure to enable a multi-hop connection. Also, the communication range in NI based network is not as desirable as eKo Pro Environmental Monitoring System. Wireless modules in NI are not solar powered, making more efforts necessary to solve its stringent power issues. Proper enclosures are also needed to deploy NI WSN in a realistic setting. eKo Pro system has very good communication. Based on our testing, it has longer communication range which partially results from a better antenna. However, it is relatively harder to connect various sensor probes to eKo wireless modules. Although eKo provides eS9000 as plug-and-play Environmental Sensor Bus, the lack of detailed documentation make it nontrivial to integrate third-party sensor probes.

STORM 3 system is totally different from WSN from *NI* and eKo. As a fully-fledged system, STORM 3 is easy to set up and much less maintenance efforts are required. It also support a large number of third-party sensor probes, making it easy to collect data. However, it is much more expensive compared to WSN from both *NI* and *Memsic*.

DATA RESULTS

We present our data results in this section. We focus on water temperature data collection from STORM 3 and eKo Pro. Our previously deployed NI WSN (Sun 2015) does not work properly due to lack of maintenance efforts. Therefore, we do not present the new data from NI WSN here.

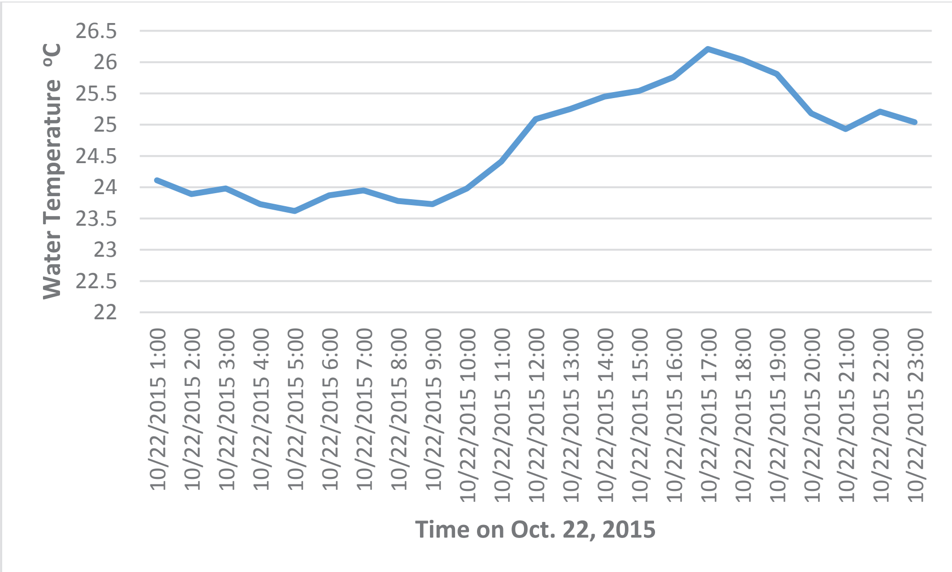

Figure 5: Water Temperature Change over one day (October 22, 2015). The x-axis indicates the hour in Oct. 22, 2015, while the y-axis indicates the water temperature value at that time.

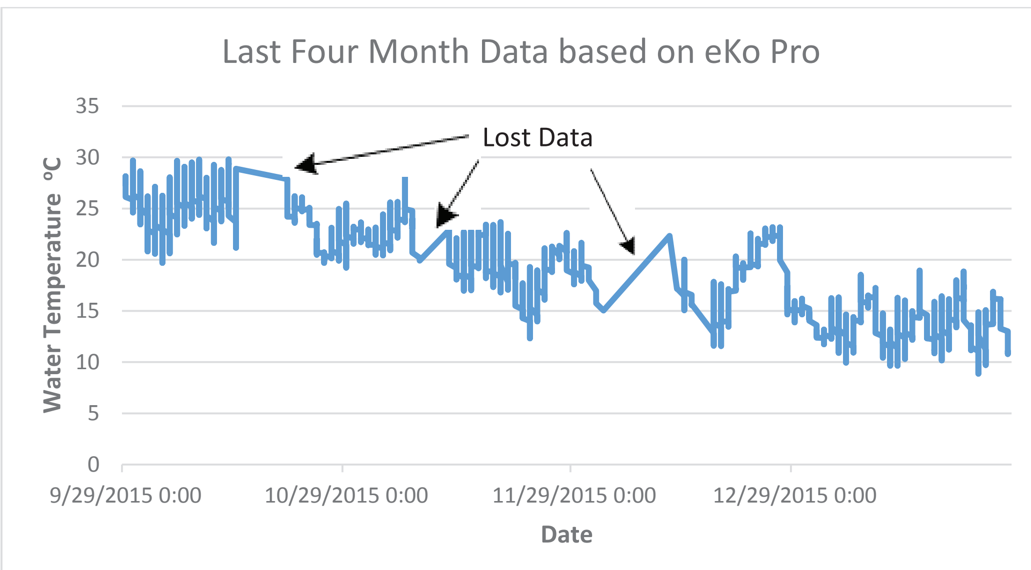

Figure 6: Water Temperature Change over Four month (September 29, 2015 to January 27, 2016). The x-axis indicates the day in every month, while the y-axis indicates the average water temperature value in that day.

Figure 5 and Figure 6 illustrate the water temperature data collected using eKo Pro. Figure 5 shows a daily temperature change in the pond on 10/22/2015. From Figure 6, we can observe that the burst data from10/14/2015 16:00 to 10/21/2015 15:00, from 11/8/2015 2:00 to 11/12/2015 14:00, and 12/03/2015 0:00 to 12/13/2015 18:00 are lost. We also observe frequent data loss at other times. This illustrates a potential reliability issue of eKo Pro.

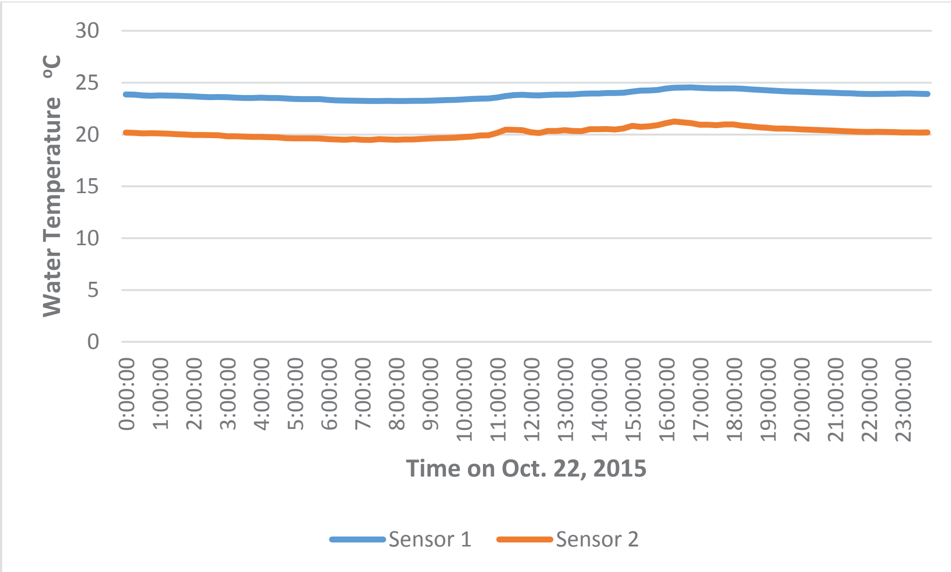

Figure 7: Average Water Temperature Change over one day (October 22, 2015). The x-axis indicates the day in every month, while the y-axis indicates the water temperature value at that time.

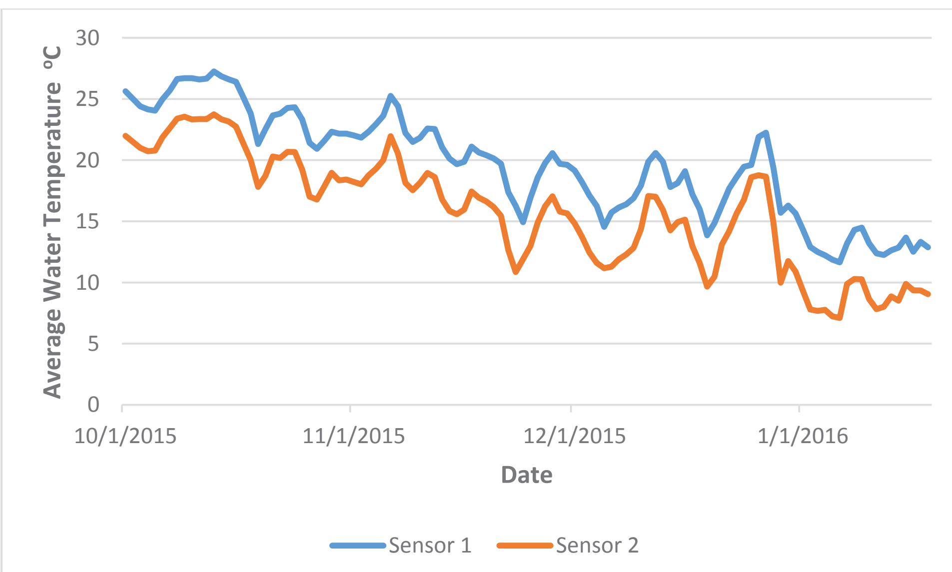

Figure 8: Average Water Temperature Change over Four month (October 1, 2015 to January 26, 2016). The x-axis indicates the day in every month, while the y-axis indicates the average water temperature value in that day.

Figure 7 and Figure 8 illustrates the water temperature data at two different depths measured from STORM 3. The data from Figure 5 and Figure 7 are close to each other.

CONCLUSIONS AND FUTURE WORK

In this paper, we report our research based on eKo Pro Environmental Monitoring system to collect water temperature data in the pond close to John Gray Center at Lamar University, Beaumont, TX. We also compare STORM 3 from YSI, NI WSN, and eKo Pro from *Memsic* based on our deployment experience.

One important future work is to how to connect more types of sensor probes to these various wireless modules. The interface between sensor probes and wireless modules are not standard. Research efforts are needed to connect them.

For example, eKo Pro provides eK2120 modules. It also provide eS9000 plug-and-play ESB board to facilitate the connection between more sensors probes and eK2100. Unfortunately, lots of efforts are still needed to make this work, this is especially true for users who are not working in this area.

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