# Smart Environmental Protection: The New Pathway for the Application of the Internet of Things in Environmental Management

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**Abstract:** The intellectual environmental management can be realized accurately by applying the technology of the Internet of Things (IOT) to sense the environmental monitoring object and to precede the data mining application based on the monitoring. Taking Shanxi Province's environmental IOT system as an example, this system had been achieved real time monitoring .The monitoring data has been applied to the total   pollutant emission reduction verification, pollutant emission charge, administrative penalties, total pollutant emission dynamic management, pollutant emission allowance trade, and environmental mobile law-enforcing system, which provides a solid platform for the environmental management .Applying the technology of the IOT, using the "Whole Circle"environmental management, combining the environmental economic means, the innovation in methods, mechanism and supervision of environmental protection system can be realized.

The Internet of Things (IOT), as the deep development and application of the information technology, has become a new direction for the breakthrough of the new generation of the information technology. The IOT technology has been applied widely in many fields and areas such as environmental protection, urban construction, transportation and food sanitation. The application of IOT in the environmental protection is notably representative and demonstrative. Environmental protection is the area with the most advanced development condition; it is the best penetration point for the development of the IOT technology.

## The concept of environmental IOT

The concept of the internet of things was first proposed by the automatic recognition lab at the MIT in 1999[1]. In 2005, *ITU Internet reports 2005 – the Internet of things* was published by ITU, which pointed out that the connections among all the people and all the things at any time and any places form the IOT and create a new dimension in the world of information and communicational technologies[2]. There is no precise concept for the IOT in environmental protection to date. According to the design of the IOT in environmental protection in Shanxi Province, it is considered to be a systemative IOT, which can achieve the scientific, refined and intellectual environmental management. It applies transducers, radio frequency identification, video surveillance, satellite remote sensing and infrared detective devices and technologies to gather pollutant sources, environment quality and risk sources among other information. With the help of the information gathered and the cloud computing techniques, deep and expanding data application can be achieved.

## The overall structure of the environmental IOT

The overall structure of the environmental IOT includes the perceptual layer, transport layer and application layer. The perceptual layer is the foundation and the data application layer is the core. The main task of the perceptual layer is to gather environmental information by the use of many different types of environmental monitoring devices. The transport layer undertakes the transmission of the environmental IOT data. The data was transmitted fast and accurately to the IOT data center via cable network, wireless communication network, satellite communication network, private network. The application layer processes the data effectively. It is used in all the sub-systems in environmental protection field, which can achieve unified intellectual control and effectively improve the level of environmental control.

The environmental IOT in Shanxi Province has installed a great quantity of terminal sensing nodes. These nodes are used to sense three key environmental monitoring objects, including environment quality, pollutant sources and risk sources. They are also used to gather and intellectually recognize the environmental information, which forms a all-covered monitoring system. The applications of environmental IOT includes the environmental quality assurance system, environmental risk prevention system, energy-saving and total amount control system, ecological compensation and ecological remediation system, environmental protection intelligent business application platform, intelligent data resource center and security protection system. These systems are designed and developed by using the environmental data gathered, with the supports of high performance computing, data mining, intellectual analyzing, cloud computing and other techniques[3]. The structural diagram is shown below in figure 1.
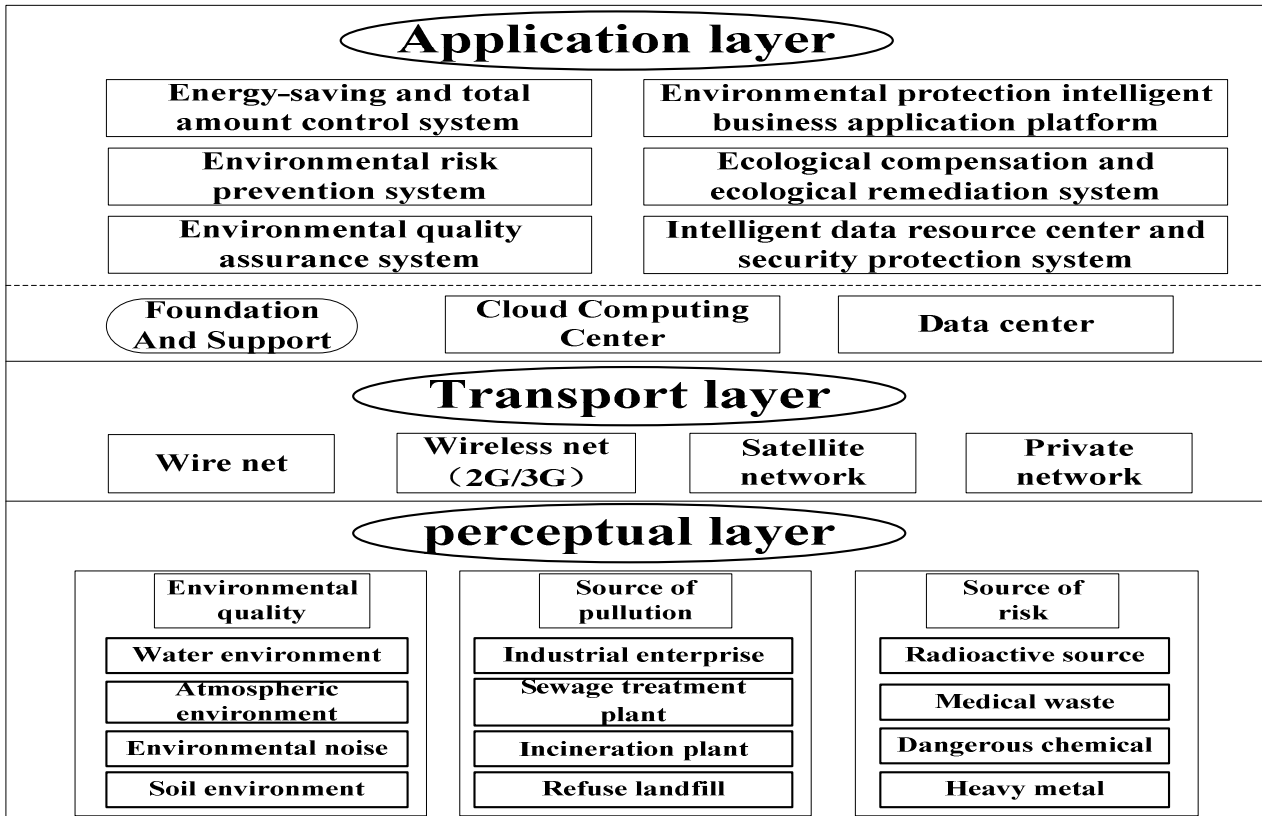


Figure1. Structural diagram of the IOT in environmental protection in Shanxi Province

### The data application of the IOT in the environmental protection in Shanxi Province

Applying the IOT technology, the "three-in-one" real time monitoring system has been implemented in Shanxi Province, including the pollutant emission monitoring , environmental protection facilities operation monitoring and video surveillance monitoring. And then, the pollution control facilities' operations and the status of the emission of the enterprises can be monitored by the system through different angles. Shanxi environmental IOT has initiated the monitoring process. The objects includes 259 environmental quality monitory points,846 important pollution discharge enterprises, 1132 flue gas outlets, 711 wastewater discharge outlets, 1323 environmental protection facilities, 173 video surveillance points and 2123 alarm control points, adding up to almost 7000 monitoring points. The automatic monitoring data has been applied to six aspects such as total emission reduction verification, emission charge, administrative penalties, total emission dynamic management, emission right trading, and mobile law reinforcement.

**Total emission reduction verification.** Based on the scientific evaluation on the current situation of environmental quality, the environmental capacity of each environmental function district and the emission reduction results were determined by the total emission reduction management system according to the target of environmental function zone, combined with the on-line monitoring data, supervisory monitoring data and model calculation method. The reduction target can be formulated once the environmental capacity of each district is known. Total emission amount is then distributed to all the districts and pollutant discharging units. Comparing the verified environmental monitoring data, the enterprises' emission data and environmental statistics data with the distributed total emission amount, the information about the total emission amount and the emission allowance that had left could be obtained. The performance of the total emission reduction was also recorded and expressed as diagrams and tables. On-line monitoring data was provided to all the major programs which have been included in the annual emission reduction verification process. These data can be used as proof to show that the operations of environmental protection devices are on track, and to verify the reduction amount.

**Pollutant emission charge.** The enterprises are charged by the environmental protection department according to the emission allowance rationed to these enterprises in the "total emission reduction management" system. Based on article ten in the *Regulations on the collection and use of emission fee*, the monthly emission data from automatic monitoring system is the main proof for the amount charged. The data from automatic monitoring system is preferred when calculating the emission fees for fire power station, wastewater treatment plants and other major polluting industries. For example, according to the *Regulation on the collection and use of emission fee*, the coal-fire power stations with a capacity of 300,000 KW and above are automatically monitored and charged for the monthly total $SO_2$ emission. As of the first half of 2012, 82,188.21 tons of $SO_2$ was emitted from 35 enterprises, and they were charged with 54.6083 million yuan.

**Administrative penalties.** Using the data from the automatic monitoring system, the major enterprises whose total emission amounts are continuously overproof will be put on record. For example, on May 5th, 2012, the emission of $SO_2$ from a sintering exhaust gas vent of a Jincheng smelting company exceeded the standard. This was spotted by the pollutant source on-line monitoring system. According to the second clause of article eighteen in *Pollutant source automatic monitoring management measures,* the environmental protection department of Shanxi Province made an administrative penalty of a fine of 50000 yuan to the company on July 19th, 2012. In 2012, there were 95 companies that exceeded the environmental protection standards. Based on the relevant regulations from the Department of environmental protection, the desulfurization electricity price was charged from 21 power stations, and emission fees were charged from 16coking plants.

**Total pollutant emission dynamic management.** The environmental protection department issues emission permits to the enterprises, sets the total emission allowance for them, monitors the total emission of them and carries out a dynamic management. Four pollutant emission reduction assessment indexes, including sulfur dioxide, chemical oxygen demand, nitrogen oxides, ammonia nitrogen, were published from the *"the 12th Five-Year Plan"*. Shanxi Province has added two more indexes, namely industrial fumes and dust. The above mentioned "4+2" indexes was implemented in Shanxi Province[4]. The "recharge at the beginning of the year, balancing at the end of the year, deducting on time, warning when exceeding the allowance" principle was followed. Total emission IC card is used for the dynamic management. There are 150 enterprises that have installed the total emission amount controller. The enterprises can charge the IC card based on the annual emission allowance. According to the pollutant source automatic monitoring data, the emission allowance is deducted by the environment monitoring center and the results was shown on the terminal devices of the enterprises. These results are used to indicate the remaining emission allowance monthly, quarterly and yearly. When the emission index is lower than the distributed amount from the emission reduction verification system, the warning program in the intellectual control module will be activated and the enterprise as well as the supervision department will be warned, and the enterprise that exceeds the upper limit will be directed into the emission allowance trading system.

**Pollutant emission allowance trade.** Using economic policies and market readjustment as means, pollutant emission allowance trade encourages enterprises to lower the pollution by improving the technologies, which can minimize the cost of environmental protection. By comparing the total emission allowance of an enterprise in the "total pollutant emission dynamic management" system and the actual the emission of the enterprise monitored by the automatic pollutant source system, the allowance left can be traded through the emission allowance trade system. The buyer will obtain their emission allowance and the seller can get some monetary compensation. By pollutant emission allowance trade, the emission right can be balanced without exceeding the total emission amount and there will be driving force for the emission reduction. Shanxi pollutant emission allowance trading center has already came into service. It has implemented the emission allowance trading for sulfur dioxide, chemical oxygen demand, nitrogen oxides, ammonia nitrogen, soot and industrial dust. In 2012, emission allowance trading has been officially included into the normalized management of Shanxi Province's environmental protection. By the end of April, 2013, there has been 278 emission allowance trading events which involves 3057 tons of sulfur dioxide, 161 tons of chemical oxygen demand, 3541 tons of nitrogen oxides, 15 tons of ammonia nitrogen, 542 tons of dust and 376 tons of industrial fumes. The total trading volume is 123.16 million Yuan.

**Environmental mobile law-enforcing system.** The Environmental mobile law-enforcing system, which is connected perfectly with the on-line pollutant source data base, is the wireless extension of the environmental law-enforcing system. It can gather the information about environmental protection from the province, cities and counties. At the same time, it can send the data obtained from the mobile terminal to the server and achieve the data exchange. Using the system, environmental protection law enforcement officer can browse the basic information in environmental protection system at any time; obtain the basic information of the enterprises and the environment situation on time. When proceeding the usual out-door inspection,environmental protection law enforcement officer can inquire about the general information of enterprises and enterprises' monitoring data, which can be found on wireless mobile devices such as mobile phone, palm computers and lap-top. All the information can be recorded on scene and printed using blue-tooth. The environmental emergencies can be forecast by mobile terminals. When the

emergency occurs, relevant information can be obtained by the mobile terminals , the contingency plan will be activated and the site situation will be uploaded, which helps environmental department with the decision making process.

## Environmental IOT-based environmental management model

**"Fully cycle" environmental management model.** By closely monitoring the source of pollution and risks and its surrounding environment/health on a thorough and daily basis, environmental IOT tracks raw materials, production technology, operation, waste management and relevant environmental impact through a cycle of "generation-growth-exhaustion-regeneration. Hence, a well-managed environmental IOT system incorporates and coordinates development of planning , approval of environmental assessment, billing for waste management, environmental supervision,environmental law enforcement, andgreen credit. Such integrated environmental IOT platform with automated management system not only monitors the environment thoroughly but also manages an entire environmental system scientifically, timely and precisely, thus functioning across industries and departments fully and authoritatively.

**Guiding environmental monitoring via economics incentives.** Environmental monitoring is, in fact, a dynamic game between the government and waste-generating enterprises, in which an environmental IOT system guided by economic incentives appears to be an optimal strategy. Environmental IOT system instantly and dynamically tracks primary data such as pollution indices, pollution levels and waste generating processes. Furthermore, an environmental IOT system incorporating pollution fees, monitoring of pollutant emission allowance trade, electricity pricing informed by desulphurization and denitration, and green loans could effectively cap total pollution level, resolve the information mismatch between government and enterprises. Economic incentives make emission trading more efficient, and incentivize enterprises to produce less waste. After experimenting with pollutant emission allowance trade system, dynamic pricing for de-sulphureted and de-nitrated electricity, Shanxi Province has witnessed a surge of enterprises actively engaging the pollutant emission allowance trade system and filing for authorized pollution discharge fees, a decrease in under-reporting pollution level, and filing for increasing in desulphurization machinery rate, efficiency and precision.

## Conclusion

Environmental IOT will not only achieve the real time monitoring of the environment quality, pollutant sources and risk sources, it will also make sure that the total pollutant emission amount control, pollutant emission charging, pollutant emission allowance trade regulation, environmental law-enforce are all incorporated in the environmental IOT system. The environmental management is converted from post processing to forecasting and preventing; from extensive to refined by the use of environmental IOT. With the development of the IOT technology, the innovation of environmental protection system, such as methods, mechanisms and supervision was inspired and supported. With the development of the sensing technology, GIS technology and video image perception technology, the accuracy, reliability will be largely improved. As the applications of data analysis, data mining and other cloud computing technologies growing deeper, the application of the environmental data is widened and deepened as well. In the future, the "smart environmental protection" can be achieved by constructing a unified environmental IOT platform, combining the environmental data and building a cloud for environmental protection.

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