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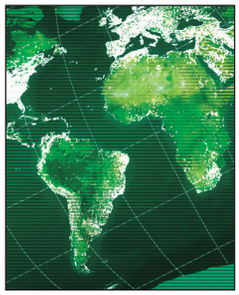

IoT Services for Solving Critical Problems in Vietnam: A Research Landscape and Directions

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Critical problems in Vietnam — such as food safety, traffic management, saltwater intrusion, and wastewater management — require novel Internet of Things (IoT) solutions. Here, the authors analyze current research and developments and propose specific IoT services as solutions.

The Internet of Things (IoT) has revolutionized several application domains by enabling efficient solutions for solving complex problems through the so-called "IoT services,"[1] which are basically (smart) services leveraging IoT sensing capabilities and analytics of IoT sensing data. Well-known application domains where IoT services play a crucial role include smart cities,[2] such as traffic monitoring and recommendation, wastewater management, public safety, and healthcare; monitoring climate change,[3] including the monitoring of floods, saltwater, and rising sea levels; and smart agriculture,[4,5] such as food safety monitoring and smart farming. In the context of Vietnam, in particular, and in developing countries, in general, these application domains are of paramount importance for developing sustainable society and living conditions.

Despite being one of the leading countries in IT outsourcing, IoT research and development in Vietnam for critical problems, such as food safety, traffic management, saltwater intrusion, and wastewater management are fragmented and underdeveloped. To provide a landscape of IoT services for solving those problems, we analyze four critical application domains in Vietnam. We highlight current IoT research and development for those critical domains and identify several obstacles. We also propose a research roadmap that focuses on developing novel software solutions to deal with the lack of efficient IT infrastructures and integrated domain knowledge for IoT services in these domains.

IoT Services for Crucial Application Domains in Vietnam

Many application domains can potentially benefit from advanced IoT services. Due to several constraints in research and development funding, along with the urgency, importance, and severity of problems in the context of Vietnam, we select

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Smart Cities and Transportation

The road infrastructures of Vietnam's big cities suffer from low quality and insufficient quantity. Improving the infrastructures requires substantial investments, in terms of money and time. With Vietnam's current economic outlook, it will take many years to see a significant improvement. Thus, leveraging advanced IoT services for traffic monitoring and planning could help improve traffic conditions using the currently available infrastructures. IoT services would enable us to continuously collect traffic data, analyze the collected data, and optimize traffic by utilizing analytic results. IoT services also help connect different vehicles to many other devices and things, such as tollbooths, surveillance cameras, and sensors tracking goods; these items can coordinate to support transportation and create a pleasant traveling experience.

There are a number of projects and commercial products for smart transportation in Vietnam, such as Magiwan (www.magiwan.com/en/), Binh Anh solutions (http://binhanh.vn), and Vcomsat (http://giamsathanhtrinh.vn), that provide features for vehicle and goods tracking using mobile communication networks (GSM, 3G), positioning systems (GPS), RFID, specialized sensors, and video cameras. From the research perspective, little effort has been spent on traffic monitoring and planning on a large scale. One effort is Smart BK Traffic for traffic monitoring and analysis in Ho Chi Minh City (http://traffic.hcmut.edu.vn). Although traffic data collected from GPS devices on public buses and motorbikes are analyzed at a datacenter, the scale still isn't very large due to the lack of suitable infrastructures and traveler participation. Overall, we need to exploit the latest technologies and techniques, such as cloud computing, sensors, data mining, and analytics to support the realistic scale of connected things in city transportation.

Food Source Verification and Safety

Food safety is a primary concern in Vietnam. Several unsafe cases have been reported,[1] including antibiotic residue, growth promoters, or heavy metals in pork; pesticide residue, nitrates, or heavy metals in vegetables and fruits; and fisheries in polluted land and water. To improve the quality of agricultural products in the context of the World Trade Organization (WTO), the ASEAN Economic Community, or the Trans-Pacific Partnership in the future, the Vietnamese government encourages farmers to follow Viet/Global Good Agricultural Practice (GAP). In this context, we see a huge potential of developing IoT services.[2] For example, IoT sensing techniques foster farm monitoring and product traceability. Using IoT technologies, farm monitoring and product-delivery data can be captured at the right time for further analytics. By combining IoT services with related information (for example, food domain knowledge, the weather, or the pollution of land, water, or air), we could provide information about the quality of food.[3]

Currently, the number of farms following the Viet/Global GAP is small (for example, according to T.H. Ngo and K.T. Duong[1] only 1.44 percent of the total area of cultivated vegetables follows GAP principles). However, as the demand for GAP products is high, products could be falsely labeled as coming from GAP farms, and currently there's no tool for consumers to verify the products' origin. Furthermore, at the farm side, we don't have suitable tools to monitor how farms operate following the GAP. Occasionally authorities manually verify the information, but this is an inefficient approach. Some projects are developed for smart farms, such as MimosaTek (https://mimosatek.com), but these only cover hardware and a few services for monitoring farms.

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and focus on four crucial application domains.

Domain 1: traffic congestion in urban areas. The development of big cities' infrastructure in Vietnam usually falls behind the urbanization process. This frequently leads to overcrowded city streets, primarily with motorbikes. At the same time, the air is heavily polluted due to exhaust fumes from vehicles and industrial factories. These factors deter economic development, but IoT services could help reverse this undesired situation. For example, IoT services could introduce novel solutions to detect traffic problems, reducing fuel consumption and air pollution as well as time for traveling within the cities (see the "Smart Cities and Transportation" sidebar).

Domain 2: agricultural productivity improvement and food safety. According to the General Statistics Office of Vietnam (www.gso.gov.vn/Default_en.aspx?tabid=491), as of 2014,

Saltwater Intrusion

The Mekong Delta region in Vietnam faces a severe problem of sea level rise.[1,2] Saltwater intrusion has emerged as an important issue for the Mekong Delta region and the other regions in Vietnam.[2] For example, in the Mekong Delta region, the saltwater can encroach inland about 40 to 60 km, in 4 or 5 months.[1,2] This causes severe problems for water sources for living and agriculture in the region.[1,2] It's difficult for farmers to use the river water for irrigation, vegetable gardens, and fruit trees. All of these factors greatly impact people's lives, especially people of the coastal region.[1–3]

Monitoring saltwater intrusion in real time and analytics solutions would help predict possible problems and planning. IoT services are clearly winning solutions to build a network of automatic salinity-monitoring stations in the Mekong Delta region, to provide real-time monitoring of saltwater intrusion. IoT services can provide quick warnings about salinity changes in some of the main rivers in the Mekong Delta. However, there's a lack of IoT solutions for such monitoring and analytics at the moment. This hinders suitable recommendation or decision-support systems for simulating and predicting saltwater intrusion in a determined period.

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Wastewater Management

Vietnam is facing with a critical problem of environmental pollution, especially due to wastewater in big cities and from industrial parks.[1] Many factories are established along rivers and they produce untreated waste disposal, causing a lot of diseases for people and aquaculture. However, monitoring wastewater pollution is very challenging due to the lack of suitable technology solutions.

In general, IoT services could support the management, operation, and maintenance of the entire sewer system, wastewater lakes, and wastewater treatment,[2] but this development is at an early stage in Vietnam. Sensors for measuring wastewaters (for example, measuring pH, salt, and phosphorus) have been used in Vietnam, but existing solutions are just applied to small-scale monitoring. In DaNang City, we investigate large-scale IoT services with flexible and extensible architectures for wastewater management and how such services interoperate with various systems, such as supervisory control and data acquisition (SCADA), weather forecasting, and environment monitoring. This will enable advanced decision making, information services, and modeling for DaNang's wastewater management systems.

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66.9 percent of the Vietnamese population live in rural areas, and work mostly in agriculture (for example, cultivating rice and coffee, or farming fish, prawns, and lobsters). However, the farms are small and the use of technology for agriculture is low. Therefore, productivity in agricultural areas is rather low, compared with that in neighboring countries. Advanced technologies are in high demand for improving the productivity in agriculture as well as the quality of products. Another related critical problem is food safety. The widespread use of chemical agents in industrial factories and farming activities makes the safety control of toxic chemical agents extremely challenging. This problem substantially affects the health of people. IoT services are naturally suited for controlling food chains and the use of toxic chemical agents in food-related products (see the "Food Source Verification and Safety" sidebar).

Domain 3: saltwater intrusion impact monitoring. The Mekong Delta region provides substantial agricultural/aquaculture products for Vietnam, including tropical fruit, rice, prawn, and freshwater fish. However, this region is submerged and suffering from saltwater intrusion at large scale in various geographical areas. Rising sea levels endanger large portions of the available cultivated land. In addition, the lack of fresh water supply from Mekong river systems accelerates the intrusion of seawater. IoT services could be used for monitoring the effects of saltwater intrusion in the region, and planning possible reactions to reduce its undesired impact (see the "Saltwater Intrusion" sidebar).

Domain 4: wastewater monitoring: The lack of proper infrastructures makes it difficult to control wastewater from factories as well as domestic activities in Vietnam. Leaking unprocessed wastewater into the environment could adversely affect people's health, along with the quality of agricultural products and wildlife. Advanced techniques from IoT could help humans closely monitor the wastewater and avoid negatively impacting the environment (see the "Wastewater Management" sidebar).

Obstacles in Developing and Deploying IoT Services

To develop IoT services for these domains, we've faced several common obstacles, as we detail here.

Weak infrastructure for IoT deployment and advanced services. Generally, computing and analysis infrastructures for IoT services are limited in Vietnam. Thus, various issues related to the information and communication technologies (ICT) infrastructure must be improved to empower IoT's potential. IoT services for such application domains will rely on the Internet infrastructure, which, in Vietnam, isn't well-suited for the scale, dynamism, and data-delivery patterns specific to IoT. First, datacenters are located on global clouds and commonly far away from IoT data sources, while in most IoT applications, data and services are consumed by local users and applications. Cloud infrastructures and services provided inside Vietnam are still rather partial and used for private purposes, or they're small-scale with public services. Second, the country has fragmented infrastructures and weak networks, which hinder the development of reliable IoT services. Wireless access networks without suitable edge services aren't powerful enough for several application domains. For example, for saltwater monitoring in sparse regions, IoT services don't work well with centralized clouds in assisting IoT services.

Lack of domain knowledge for analytics. In addition to IoT sensing data, the heterogeneity of data sources and knowledge of application domains must be integrated. Such data sources and knowledge, such as about air/water pollution, weather/climate, traffic, and agriculture, are strongly related to conditions and expertise in Vietnam. For example, the traffic behavior with motorbikes in Vietnam is quite unique, and social networks and multimedia sources document traffic problems quite well. However, traffic patterns and knowledge haven't been gathered systematically, to enable efficient traffic planning. In the four focused domains, there's a lack of useful data sources and knowledge as well as proper tools for dealing with such data and knowledge. Essentially, the historical knowledge needed to serve as ground-truth data in these domains is often missing.

Lack of IoT research networking and awareness. Research and awareness about IoT services are quite limited. Do-it-yourself small-scale IoT applications (for example, for home monitoring) are quite popular, but they're designed to solve very specific and narrow issues. Thorough and thoughtful investigation is currently lacking (but sorely needed) when looking at the IoT potential for large-scale applications. For example, while IoT services for food safety and agriculture have a strong impact on the population outside the cities, the level of awareness of such IoT potentials and solutions is low in the countryside. Interdisciplinary collaboration is another major problem. For IoT services to support these crucial application domains, a wide range of knowledge from different disciplines, such as computing, statistics, and application-specific domain knowledge, is required. However, this type of collaboration is limited and fragmented in Vietnam for cultural and economic reasons. There are precious few efforts to set up initiatives that intertwine the related technologies and knowledge in a common research and educational program.

Research Roadmap

We must solve several challenges for the research and development of IoT services. Many of them require national initiatives and go beyond technical and scientific ones. Specific services within particular domains require specific treatment. Hence, we limit our discussion to a short-term perspective — a 5-year vision — of the following foundational technical and scientific research areas (RAs) essential for all of the aforementioned domains.

RA1: Improving Infrastructures through Novel Software Solutions

New network infrastructures and high-performance computing systems are desirable. However, they require substantial investment in long-term perspectives. Thus, we concentrate on the following novel software solutions to tackle infrastructure problems.

Develop software solutions that leverage edge computing models to deal with bottlenecks in network and computing infrastructures. Such models[6] enable distributed computation close to the large amount of data produced by IoT devices. In the context of Vietnam, these models are important because we don't have big, centralized datacenters/clouds like other countries. Furthermore, such models would fit well to the monitoring and analytics in sparse geographical zones, such as in agriculture and saltwater intrusion.

Optimize communications between datacenters and edge-computing nodes as well as between multiple datacenters (in the future) using software-defined networking and network function virtualization (SDN/NFV)[7] as the focus. Although SDN/NFV are hot topics in other

places as well, in Vietnam we need to exploit them intensively because our IoT services either have dense networks of moving IoT objects or geo-sparse, distributed weak networks of IoT devices. For example, in big cities, IoT services for traffic in Vietnam will rely on a lot of moving objects (such as people's mobile devices while they ride on motorbikes) due to the lack of fixed IoT sensing systems. This would require novel solutions to deal with different, dynamic IoT dataflow and access patterns.

Develop security and privacy frameworks for IoT services. This is a global challenge, but it's particularly crucial in Vietnam due to the lack of well-established security and privacy practices and knowledge. Research should focus on two distinguishable situations in our application domains. First, we'll have IoT services developed and deployed in sparse regions, such as for smart agriculture and saltwater intrusion. Second, IoT services can rely on a large-scale participation of human sensing (for example, for traffic, which is a suitable model in Vietnam,[8] in a very dense network of moving objects). These situations require very different security and privacy mechanisms and policies to enable IoT service operations.

RA2: Integrating Domain Knowledge and Analytics

Incorporating domain expertise with IoT data is challenging, as a lot of domain knowledge still needs to be gathered and made available for data analytics. With so many types of knowledge being uniquely associated with special contexts in Vietnam, it makes this task difficult. To contend with this, we suggest the following concrete actions.

Develop a suitable scheme where large domain knowledge bases can be built up by domain experts and citizens using social networks and crowdsourcing of knowledge. Considering that social networks are very attractive for other types of conversations in Vietnam, they could be a useful means for gathering experts and citizens to provide knowledge. Crowdsourcing of knowledge for crucial problems in Vietnam could benefit a lot from the concept of "citizen science," especially for agriculture, saltwater intrusion, and traffic knowledge, because citizens have extensive knowledge through their daily interactions in the domains, while the number of experts is limited and often the experts are located in limited areas (mostly cities). In this respect, experiences from other countries, such as in Africa,[9] would be useful.

Develop different information-as-a-service and knowledge-as-a-service infrastructures at the national level for different application domains by leveraging cloud and data service models. In particular, we should focus on current high-demand knowledge such as smart cities (knowledge about the environment, traffic monitoring, urban planning, and traffic modeling); agriculture (knowledge about aqua farming, water quality, animal production, and dairy production), fruit farming production, and disease treatments; food technology/quality (knowledge about food processing, safety control, and quality management); and water management (knowledge about water sources and water flows).

Enable efficient ways to bring different experts from different domains. To foster and implement collaboration among experts for knowledge integration, we need to have suitable frameworks for joint efforts, such as organizing multidisciplinary seminars and workshops among higher education and research institutions. In the context of Vietnam, we could achieve this only if funding sponsors (government or industries) put a focus on basic multidisciplinary research. Funding sponsors shouldn't favor the current approach, which focuses on application-oriented, silo-disciplinary research.

Given these concrete actions and the existing available (open source) software for, for example, cloud technologies, crowdsources, IoT, knowledge management, and advanced data processing frameworks from the developed world, we expect that certain goals in our roadmap would be achieved in the next five years. This, of course, can't be done without appropriate education and research funding programs, which are other important issues that are out of the scope of this work.

Concentrating mainly on four crucial domains in Vietnam, we analyzed the importance of IoT services and obstacles for developing IoT services. The focusing points of our roadmap are for developing novel solutions by leveraging existing technologies to address specific conditions in Vietnam. Obviously, there are other crucial issues as well — for example, better network infrastructure deployment, training, and education program enhancement, and research funding strategies. However, they require much more thoughtful and long-term substantial investment that goes beyond the capabilities of research and development in universities and in small and medium enterprises. Furthermore, although our study is focused on Vietnam, such problems are inherent in other developing countries. Therefore, we hope to collaborate with others to foster the development of common IoT services for developing countries.

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