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Configuring Availability, Reliability, Maintainability – A Taiwan's air-sea port as an example

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Abstract— **Reliable communications and spatial connectedness are essential for critical operations. A reclamation site near the Kaohsiung City coastal infrastructure plants has been proposed as a new location for the city's international airport, which was built in the 1990s. In this paper, an alternative is suggested: reliably connecting new runways to the original terminal through underground passages. This alternative offers greater flexibility for airport development and for operations at neighboring plants. To ensure the provision of services and security, we created prototype surveillance-control networks using optimal-degree spider-web networks to be placed around the port area and along connected critical passages of the city to cope with radio interference and the lack of detecting availability. The connectedness of the radial ring road configuration of Kaohsiung and other cities has been mathematically proven to be robust. Such a configuration can offer integrated response capabilities even if two paths connected through the prototype spider-web network configuration are destroyed. For sparsely populated areas, the use of probes of wireless sensors, with cube-connected cycles, is proposed. Facilitating dedicated short-range communications, including radio frequency identification (RFID) applications, along roads through the aforementioned surveillance-control networks can provide greater reliability for mobile business and logistic services involving multiple modes of transportation, and can promote tourism.**

Index Terms—**dedicated short-range communications, detection availability, radio interference, radio frequency identification (RFID).**

I. Introduction

Taiwan has relatively limited natural resources. Consequently, the sustained development of Taiwan strongly depends on the firm establishment of global trade-related operations including air and sea port facilities, land transportation and logistics, and stable political order; moreover, a cultural atmosphere favorable to the social marketing of products must be fostered [1]. Accordingly, it is necessary to focus on satisfying integral requirements for global trade such as providing security along routes to ensure safe land transportation and logistics, empathetically highlighting capabilities to deal with global business, and efficiently connecting air and sea ports.

Kaohsiung is the main seaport (Fig. 1) and southern growth pole of Taiwan. It is notable for its large deep-water port, which accounts for approximately three quarters of all international freight transport to and from Taiwan, and which was the world's third busiest seaport in 1999, before being overtaken by Yangshan Port off Shanghai. The northern growth pole, Taipei, is the capital of Taiwan whose nearby seaports are administered in Keelung port, approximately 30 km from Taipei Railway Station, and is the second largest port in Taiwan. In addition, Northern Taiwan has two international airports: one in Taipei City and one in Taoyuan. The Taoyuan International Airport, which is the larger of the two and is considered the gateway to Taiwan, was opened in 1979 and is approximately 35 km from Taipei Railway Station.

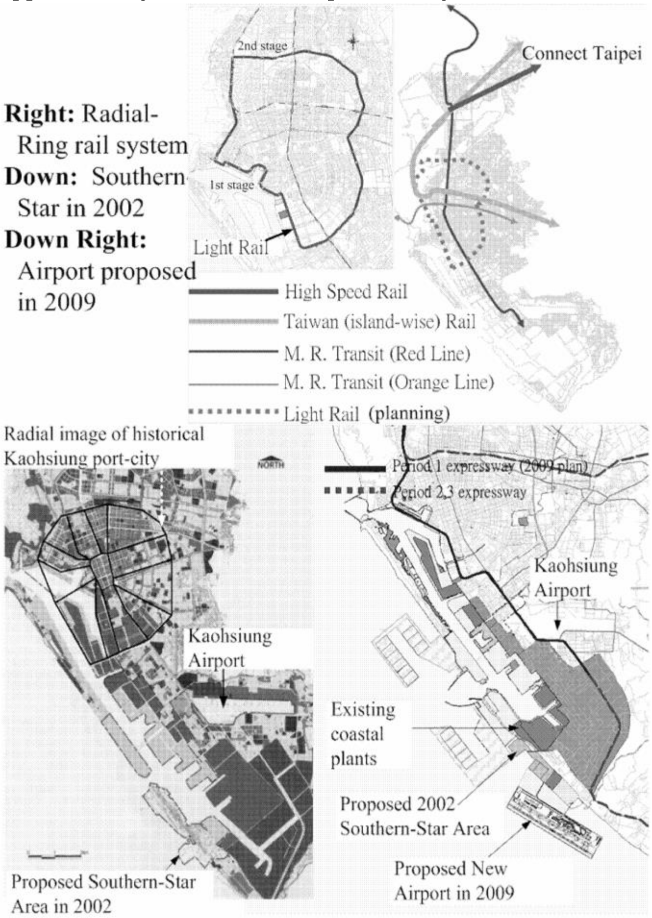

Fig. 1. Historical radial-ring and southern-star in Kaohsiung port-city. (map source: Kaohsiung city government, [2, 3])

In the 1990s, to sustain Kaohsiung's operational productivity and stimulate its economy, the central government proposed a comprehensive port city plan. The plan included combining the domestic and international airport terminals and developing the Southern Star coastal reclamation area, an approximately 500-ha plot compactly filled with industry slag, municipal waste, and soil from mudslides occurring during seasonal typhoons [3, 4] (Fig. 1). Specifically, a new international airport was planned in the

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Southern Star area to replace the existing international airport [3].

The promotion of the Kaohsiung airport is essential for balancing the political and socioeconomic differences between Northern and Southern Taiwan as well as for reducing international transportation-related costs in Southern Taiwan. As demonstrated by the airports in Changi (Singapore), Hong Kong, and Incheon (R. Korea), new airports constructed on reclaimed coastal land can offer advantages, such as improved and more flexible airport operations (e.g., longer runways for larger planes like the A380), ecofriendliness, and the possibility of combining air and sea transportation to create new service opportunities and reduce operational transportation costs.

Moreover, the aforementioned three airports, and many other airports worldwide, collaborate with neighboring seaports to enhance the efficiency of the value chain. Specifically, certain heavy industry products can be economically transported by air instead of sea. Furthermore, for the same products, different transportation modes may be chosen on the basis of accumulated consumer demand, product quality, and warehouse costs. In addition, the choice of multiple transportation modes may attract travelers. In Taiwan, attracting tourists by providing them with the choices of air and sea transport is considered strategically important because the view of Taiwan from the sea is a popular draw, even though the travel time between cities by sea is relatively long. In addition, industries with highly innovative value-added attributes, which Taiwan aims to promote, generally require the convenience of both air and sea transport.

In Kaohsiung, sea transport to some crucial plants (including those related to energy supply) located near the front docks of the port will be obstructed by the Southern Star area, potentially affecting the development and operation of the plants. Hence, economic returns from investments in those plants, the existing airport terminals, and the Southern Star area should be comprehensively analyzed. The airport at Schiphol (the Netherlands) shows that the main focus should be on how to effectively use sea and land facilities and resources, promote tourism, and flexibly develop space. Such flexible development is related to land use design. For example, space for runway extensions can be reserved by adaptively providing sufficient green spaces or woods, which can obstruct the view of plants. Even when there is considerable separation between new runways, they can be connected by robust underground passages and communications systems [2, 5-7]. Regarding cost-effectiveness and environmental protection, the sizes of the largest ships and airplanes increase only when appropriate technologies and operation platforms become available. The 3.8-km runway of Schiphol airport was corroboratively constructed with tunneling to provide the required viaduct for airplane operation [7].

A long runway can be priory constructed close to the Southern Star area. Such a runway would be especially suitable for air freight transportation because the integrated seaport and airport can potentially offer superior services, likely local industry-specific services, by efficient scheduling and space utilization. For passenger travel, international airlines can consider fully employing all their planes, and even choosing the largest planes if this airport can be acted as a rolling hub to flexibly serve potential customers especially on holiday seasons, e.g., Chinese lunar New Year. Further, such an airport with a long runway can help support the trip of larger airplanes which may stop at several cities to get more service chances - in other words, probably stop early in the morning or late at night.

Despite existing uncertainties, providing visitors to Kaohsiung with a high level of service is imperative, particularly in terms of reliability and a pervasive communication environment for promoting mobile business in the information age. In the next section, a literature review of problems such as blind spots, material interference, and network resilience (fault-tolerance) is presented, and the problems are discussed. For solving those problems, a spider-web surveillance-control network is prototyped and mathematically explained in Section IV, and major features (i.e., availability, reliability, and maintainability) are subsequently outlined. Conclusions are presented in the final section.

II. Literature Review

From small settlements to big cities, the traditional dominant cities generally can have relatively convenient accessibilities, and enough living resources, and then it can be developed step by step - inherently in a radial-ring configuration centered in the original settlement [8-10].

Appropriate security ring formations or the defense-in-depth concept have been proclaimed [11] because they help overcome various challenges can be met. It has been proved that radial-rings (spider-web) can have more fault-tolerance than single rings can have [12]. Due to technology development (e.g., stealth technology) and prevailing terrorism, which is a politically sensitive consideration in the development of new cities [13], it is necessary to prevent blind spots and devise a fault-tolerant (Fig. 2) mechanism in surveillance systems. In particular, defensive radial ring spatial formations are critical for the safety of air and sea ports. Moreover, ring formations should be multicentered; hence, the interconnection of several ring formations for adaptable hierarchical or integral operations has also become a key requirement.

An examination of casino surveillance systems, in which more than eight cameras may be required to monitor a game table, reveals that the line-of-sight environment can be dynamic and that unexpected faults can exist. However, the traditional approach to traffic surveillance involves the use of only one or two cameras typically installed in the middle of a section of a road. Such an approach cannot provide left- or right-side views of vehicles in the left- or right-hand traffic system, respectively. Thus, traffic incidents or accidents can occur because of the absence of a sightline in a detection system; for example, in a right-hand traffic system, a car that has caught fire on the right side can cause the death of the drivers and passengers of other cars who did not receive a warning in time [22].

How the (two) eyes or ears of a human (or essentially any living creature) are used for comparing images or sounds from slightly different positions or times, is termed as parallel or dual surveillance to define such (cooperative) function of the devices. It is noted that two or more sensors can naturally be packed together (e.g., a probe) to help got a collaborative work. Wireless communications are increasingly being incorporated into urban transport. In invisible applications at airports and seaports, wireless spoofing or interference devices, including personal privacy devices (PPDs) [23] used by truck drivers worldwide to evade legal wireless tracking through the Global Positioning System (GPS), have exhibited adverse effects on traffic control [23–25].

Similarly, for invisible wireless information acquisition, the physical environment, detection availability, system reliability, and system maintainability should be considered comprehensively (Fig. 2). Specifically, information devices should be designed to receive different radio frequencies; nevertheless, the sensitivity of radio frequency identification (RFID) can be affected by the environment, moisture, and waterlogged conditions [26, 27]. Increasingly high quality information integrity will be required to accommodate the growing needs of daily life and mobile businesses [28]. Consequently, detection and information networks should rigorously consider various radio frequencies, fault tolerance, systematic maintainability, and radio interference.

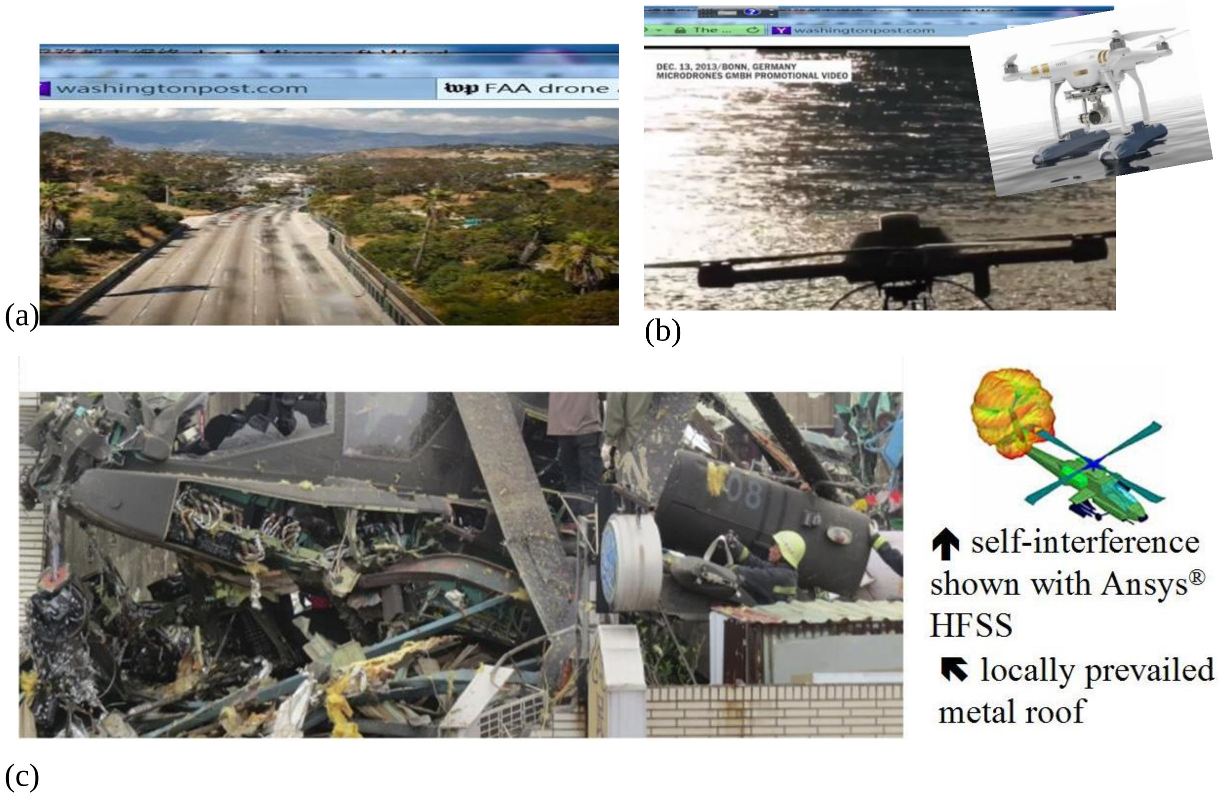

Fig. 2. At present, unacceptable risks are posed by potential control faults of aerial vehicles globally. Shown here are multicausal incidents related to (**a**) highway administration [14]; (**b**) port administration [14, 15, e-catalog of ***shapeways***]; (**c**) homeland security, namely a helicopter crash in Taiwan on April 26, 2014 [16-21, e-catalog of ***Ansys***].

In general, for maintaining large-scale security tasked networks, node-by-node operating inspections by a single inspector without repeats and loss [29] (i.e., all nodes being in a sequential order or having the Hamiltonian property in graph theory) are as efficient and effective feature. Further, the frequency spectrum should be managed through frequency hopping to prevent the concurrently use; however, frequently changing channels may cause network instability, thereby necessitating frequent route maintenance is also an aspect of routine maintenance operation [25].

The application of the principle of coding [30, 31] to identify messages is recommended for enhancing the quality of radio communications (e.g., through massive multiple-input and multiple-output [MIMO] systems) [32, 33]; the enhanced quality can improve information integrity and has considerable potential in developing mobile business and to help operating security tasks accountable. Moreover, to enhance safety and provide universally perceptible information in a sustainable manner is desirable by applying wireless technology to promote the welfare of human beings [34].

Hence, the formation of an adaptable array-like network of sensors along paths is discussed. Such a kind or networks can have the availability feature preventing the occultation of images caused by lanes of three dimensional vehicles; and can provide the configuration related performance of maintainability and reliability based on the mathematical proofs [35, 36]. Further, such features are gaining more importance in the planning of contemporary global air and sea port cities [37] to promote (mobile) business, the integrated tracking of services provided to passengers, and freight tracking through wireless communications involving radiant frequency technologies, which naturally need the feature of security and integrity.

Coding has been used to transmit fully diversified signals independently (according to time or frequency division). Furthermore, technologies used for interference cancellation in spatiotemporal dimensions have recently been modified [32, 35] to evaluate the interference caused by vehicle drivers using wireless antitracking devices, materials such as metal or water, or intentional actions [38]. Hence, technologies used for mobile communication, which is characterized by intrinsic information diversity and increasing demand, must be adapted to address intentional interference cancellation through the aforementioned dual-surveillance based means, which can be featured with availability, maintainability, and reliability in spatial governance.

In public spaces, although personal privacy permits people to use personal communication devices of their choice (personal aspect) [39], it also affects public safety (public safety aspect) [24]. Regarding personal privacy and safety, new means of authorization and authentication should be considered, as they are in the networks proposed in this paper. Regarding public safety, interference countering should be implemented in the infrastructure, and it need not be confined to only PPD-using truck drivers [39]. Moreover, it is practical to use available relatively low-layer equipment, possibly in combination with mathematical techniques [40], to prevent interference problems and enhance the integrity of wireless communications.

III. Real-Time Integrity for Kaohsiung – as a Smart Port City

Dual surveillance, similar to that used to counter the lack of sightline availability, can help counter material interference (information transmission obstructed or deviated by materials such as metal or water), and can help overcome frequency interference or multipath effects through analysis of acquired data for different positions and time sequences by using parallel or mutually independent Hamiltonian paths (MIHPs; discussed in Section IV) [41]. Moreover, a series of such dual-surveillances could be located along the path at blind-spot concerned positions to get parallel and thorough recordings as the diagnostic tool. As to waterways, which have more adversary conditions due to water's radio interference possibilities, countering boat collisions, smugglings, and pirate ships need to be actively prepared [42-44]. In other words, dual-surveillance based information networks are appropriate for busy waterways; moreover, the detection devices of these networks must be floatable [15, 45].

Terrorist often target airports and places which can cause attentions and such attacks may occur at any time and at any location, even at several locations concurrently. On the landside of airports, monitoring vehicles can be concealed behind other vehicles. On the airside, landing and departing planes can be involved in accidents resulting from a communication or surveillance failure. Such accidents can be prevented by employing a parallel mechanism. Such mechanisms already exist on airsides; an example is the cooperative unit of two practical fault-tolerant radars or a group of multiple sensors deployed at the airfield (such as the advanced "airport surface detection equipment" (ASDE-X) (a kind of ground radar) for overcoming problems such as blind spots and false images or for repair necessary airfield management facilities like lighting. However, the network performance at airports can be further improved.

For invisible applications such as RFID, dual surveillance can help overcome problems associated with material interference (information transmission obstructed by materials such as metal or by water); specifically, a method similar to that employed for overcoming the problem of absence of a sightline in vehicular traffic systems can be used, which can help deal with frequency interference or multipath effects through the analysis of acquired data for different positions and time sequences by using MIHPs. Analogically, the cooperative function of the devices used for parallel surveillance is similar to how the two eyes or two ears of a human are used for comparing images or sounds from slightly different positions or times.

Moreover, such dual surveillance could be positioned along a path at blind spots to obtain parallel and detailed recordings for use as a diagnostic tool. Such parallelism is recommended for critical and dynamic environments. Specifically, the devices along the path, at exterior or interior positions, can be integrated into an area-based resilient supervisory control and data acquisition (SCADA) network system [22]. In addition, cellular communication systems, GPS, and geographic information systems can be integrated naturally to further strengthen responding capability; including preventing terrorists' intentional concurrent attacks which probably use contemporary low-cost unmanned aerial vehicles.

A mathematical, optimal-degree (the minimal number of links connecting a node being regular three in establishing a dual-surveillance based network whose nodes and two nodes linked as one independent unit are regularly linked), spider-web network prototype, $SW(m, n)$ (see Section IV), is proposed for airports and neighboring areas for wireless and heterogeneous SCADA networks on paths (Fig. 3(a)) as well as for interference-free cellular communications (Fig. 3(b)) [22]. Furthermore, a SCADA network that has fault tolerance and an order (properties: 1-edge Hamiltonian and 1p-Hamiltonian; see next section) and that can be used on both the airside and landside for enhancing maintenance efficiency and effectiveness is proposed. Such networks can be adapted to accommodate surveillance modes such as surveillance of both forward and backward directions and for facilitating SCADA operation when one lane of a path is under maintenance. Moreover, such networks are scalable; in other words, they have the flexibility to be extended along a path or survey (water) area to meet future requirements (Fig. 3(c)) [46].

IV. Mathematical Preliminaries

Communication networks are usually illustrated by graphs in which nodes represent processors and edges represent links between processors. Let G = (V, E) be a graph if V is a finite set and E is a subset of {(a, b) | (a, b) is an unordered pair of V}. A path is delimited by $(x_0, x_1, x_2, \ldots x_{n-1})$. A path is called a Hamiltonian path if its nodes are distinct and span V. A cycle is a path of at least three nodes such that the first node is the same as the last node. A cycle is called Hamiltonian cycle or Hamiltonian if its nodes are distinct except for the first node and the last node, and if they span V.

A bipartite graph G = (V, E) is a graph such that $V = A \cup B$ and E is a subset of $\{(a, b) \mid a \in A \text{ and } b \in B\}$; if G – F remains Hamiltonian for any F = {a, b} with $a \in A$ and $b \in B$, then G is 1_p-Hamiltonian. A graph G is 1-edge Hamiltonian if G - e is Hamiltonian for any $e \in E$; moreover, if there is a Hamiltonian path between any pair of nodes {c, d} with $c \in A$ and $d \in B$, then the bipartite graph G is Hamiltonian laceable.

The bipartite spider web network, SW(m, n), is the graph with the node set $\{(i, j)| 0 \leq i<m, 0 \leq j < n\}$, where m and n are ≥ 4, even integers such that (i, j) and (k, l) are adjacent if they satisfy one of the following conditions: (1) $i = k$ and $j = l \pm 1$; (2) $j = l$ and $k = i + 1$ (**mod** m) if $i + j$ is odd or $j = n - 1$; (3) $j = l$, $k= i – 1$ (**mod** m) if $i + j$ is even or $j = 0$. SW(m, n) (Fig. 3) is proved to be 1-edge Hamiltonian and 1_p-Hamiltonian [12]. Thus, the fault-tolerance involved is systematically based, i.e., prototyped to capably deal with the unexpected incident at any time and at any location, even at several locations concurrently. Moreover, SW(m, n) are Hamiltonian laceable [47], see Fig. 3(a).

The number of links connecting a node is called the degree; networks regularly having smaller degree are generally economic [48]. Two Hamiltonian paths, $P_1=(u_1, u_2, \dots , u_{n(G)})$ and $P_2=(v_1, v_2, \dots , v_{n(G)})$ of G from u to v are independent if $u = u_1 = v_1$, $v = u_{n(G)} = v_{n(G)}$, and $u_i \neq v_i$ for every $1 < i < n(G)$. A set of Hamiltonian paths, $\{P_1, P_2, \dots , P_k\}$, of G from u to v, are mutually independent if any two distinct paths in the set are independent from u to v [49]. It was found that SW(m, n) has the performance of at least two MIHPs between any pair of bipartite nodes [6, 41] (Fig. 3).

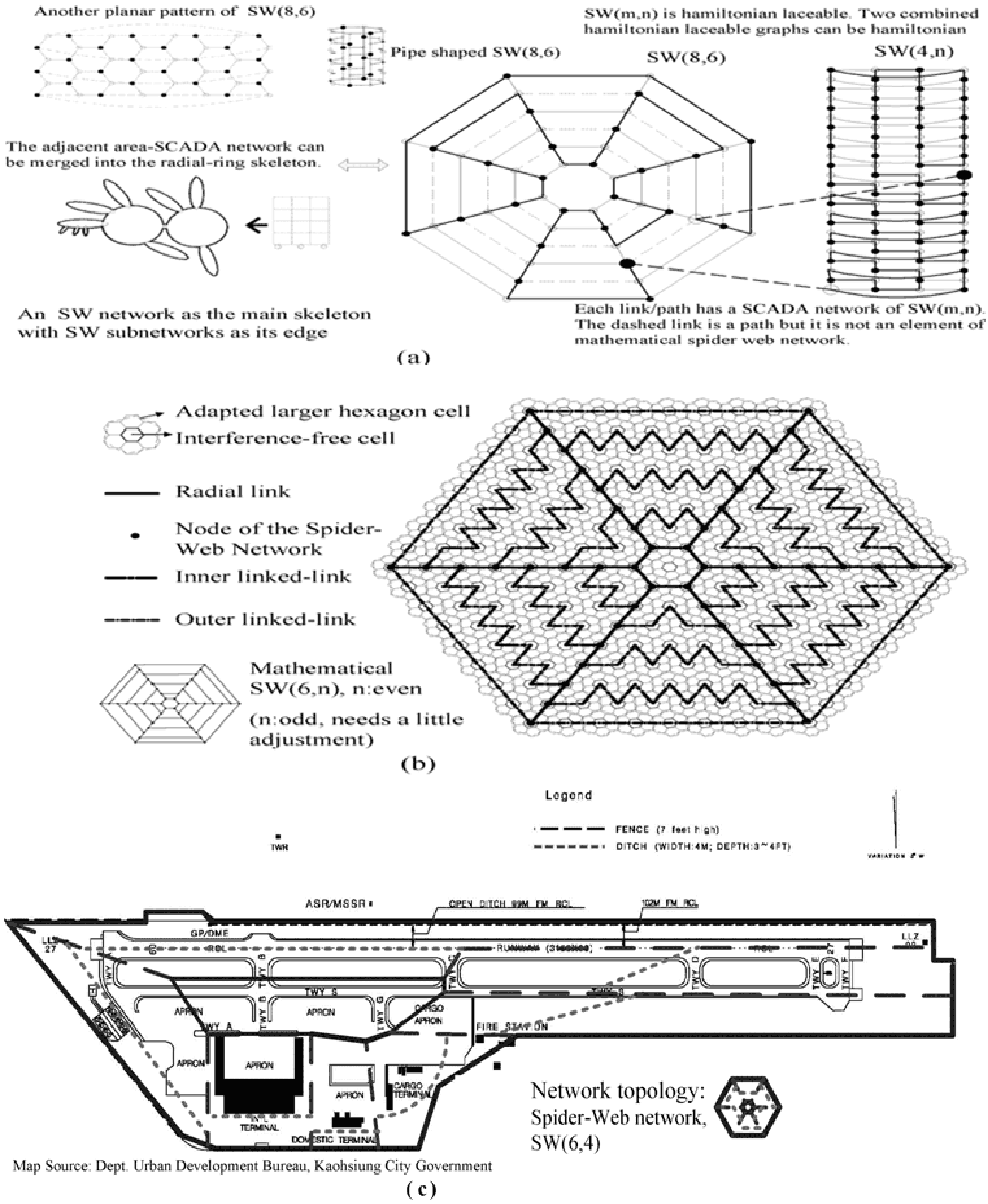

Fig. 3. Spider-web network applications. (**a**) area-based SCADA networks, (**b**) interference-free cellular communication networks (*SW*(6,*n*)), and (**c**) a proposed SCADA network for the Kaohsiung airport.

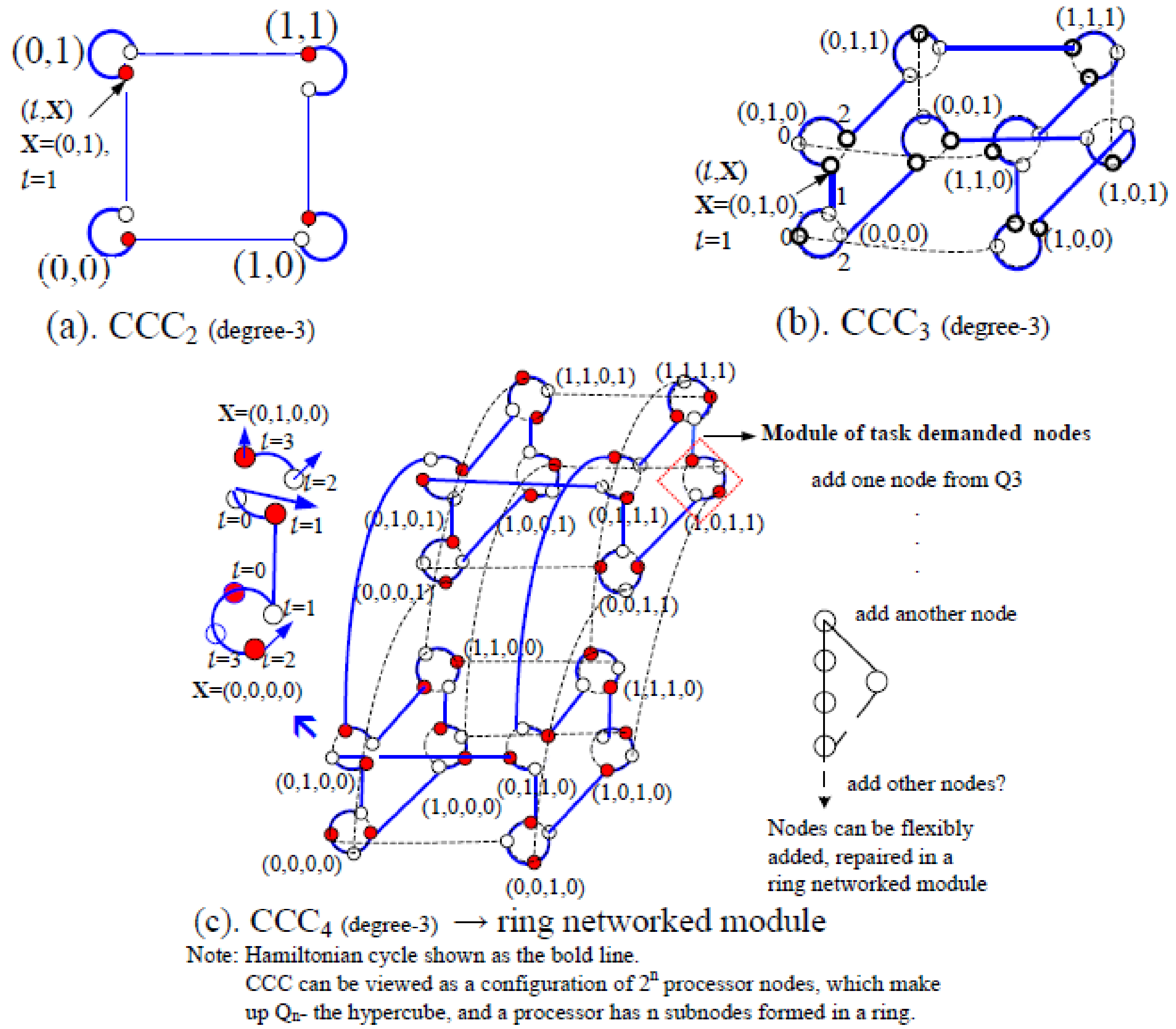

Fig. 4 Relationship between Cube-Connected-Cycles and Hypercubes. (**a**) CCC_2; (**b**) CCC_3; (**c**) CCC_4 and ring networked module [50].

The definition of the hypercube is given as follows. Let u = $b_{n-1} \dots b_i \dots b_0$ be an n-bit binary string. For any j, $0 \le j \le n-1$, we use $(u)^j$ to denote the binary string $b_{n-1} \dots \underline{b}_j \dots b_0$. Moreover, we use $(u)_j$ to denote the bit b_j of u. The *Hamming weight* of u, denoted by wH(u), is the value of $|\{0 \le i \le n-1 | (u)_i = 1\}|$. The hypercube Q_n consists of 2^n nodes and $n2^{n-1}$ links. Each node corresponds to an n-bit binary string. Two nodes, u and v, are adjacent if and only if $v = (u)^j$ for some j, and we call link $(u, (u)^j)$ j-dimensional. The Hamming distance between u and v, denoted by h(u, v), is defined to be the number of elements in $\{ 0 \le i \le n-1 \mid (u)_i \neq (v)_i \}$. Hence, two nodes, u and v, are adjacent if and only if h(u, v) = 1.

The cube-connected-cycles graph CCC_n has $n2^n$ nodes labeled as $(l, \mathbf{x})$, where l is an integer between 0 and $n-1$ and $\mathbf{x}$ is a processor node with an n-bit binary string. Two vertices $(l, \mathbf{x})$ and $(l', \mathbf{y})$ are adjacent if and only if $\mathbf{x} = \mathbf{y}$ and $|l - l'| = 1$ or $l = l'$ and $\mathbf{y} = (\mathbf{x})^l$. In the final condition, $\mathbf{x}$ and $\mathbf{y}$ differ only with regard to the position l. The edges that connect $(l,\mathbf{x})$ to its neighbors $(l + 1,\mathbf{x})$ and $(l - 1,\mathbf{x})$ are called cycle edges. Moreover, these cycle edges form a cycle of length n, which is called a fundamental cycle and is defined by $\mathbf{x}$. For $n = 2$, CCC_n is simply a cycle graph of length 8. Furthermore, $L(n)$ is the set of all possible lengths of the cycles in CCC_n [51; Fig. 4].

V. SIGNIFICANCE

A. *Using scattered land lots through effective communication and management*

Just as advanced ground radar systems (e.g., ASDE-X) [46] are used for dealing with blind spots on an airfield, scattered land lots can be integrally put to common use if they can be effectively monitored and controlled to satisfy operational requirements. It is proposed that instead of closing the present terminals, the Southern Star area and present terminal area should be connected through networks featuring detection availability and interference diagnosis capability along the connecting passages and on new airfields (e.g., Fig. 3c). This approach can prevent public anger at previous expenditure on the existing international terminal only for it to be closed and moved. Moreover, such an approach can help create conditions for offering reasonable grandfather rights to the original coastal plants without sacrificing social justice. Nevertheless, connecting passages can be arranged with future developments (e.g., airport city development) comprehensively. The land-use renewal suggested in the proposed alternative may increase the likelihood of improving the view of the coastal plants and reducing their environment impact. However, the plan proposed by [3] can still be considered.

B. Reliable parallelism supports network performance

False detections may occur for many reasons such as multipath effects, node or link (transmission) faults, and a combination of these reasons. After an adaptable dual surveillance system is configured as a basic detection-availability platform, systematic fault-tolerance, connectivity, and management efficiency enhance detection availability. Furthermore, a diagnostic MIHP can be generated to analyze adverse conditions on the basis of independent, alternative, time-series recordings for data mining or problem diagnosis. This is similar to physicians employing independent alternatives and time-series records to diagnose a disease. In addition, the MIHP parallelism can facilitate inherent dynamic authorization and authentication during routine operations; i.e., if the unauthorized sequence is abnormally used to replace the predefined, then it naturally can show alarm messages [22].

C. Benefit both passenger and freight transportation

Mobile commerce can be promoted by using the proposed wireless communications networks, which are characterized with data integrity and reliability. Similarly, such kind of networks is disabled- and elderly-friendly because their features can also aid the disabled or the elderly [22]. Detection availability for applying RFID, which is especially necessary in logistics processing, can also be guaranteed. MIHP-related authentication and authorization can also be initiated using RFID, and active RFID can be more effectively reauthorized to ensure privacy.

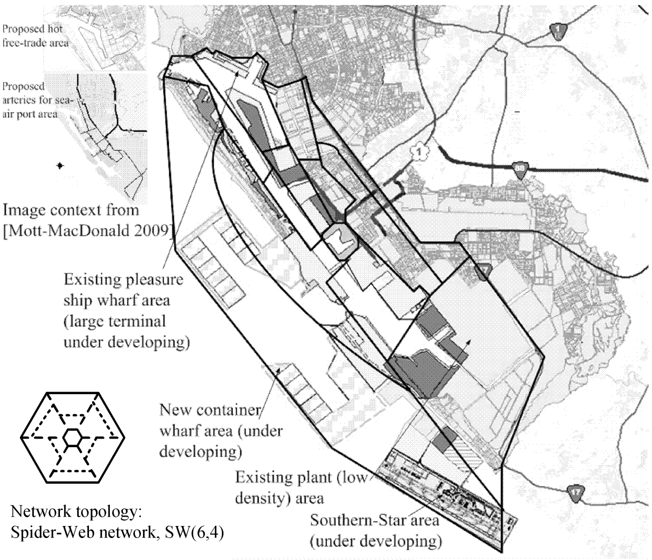

Fig. 5. A conceptual main area SCADA network proposal for Kaohsing air-sea port area [3]- subnetworks not-shown.

D. Resilient area-based management system

The Hamiltonian laceability can help flexibly integrate individual SCADA networks along paths, including interior paths, with area-based SCADA networks. If such networks can be adapted to have an inherent "spider-web" skeleton (Fig. 5), then they can show performance comparable to that of spider-web networks; in other words, they can retain their response capabilities even after two paths of a SCADA network have been seriously compromised.

VI. Conclusion

At present, promoting pervasive communications is one of the strategies for improving regional and human welfare. The quality of communication networks, such as systematic reliability and integrity, should be addressed. More specifically, this quality includes fault tolerance, working orders for maintenance or inspection, detection availability for real-time monitoring, wireless security or privacy, and systematic diagnosis capability for countering false alarms or compromised information acquisition resulting from noise or the multipath effects of wireless communications.

Dual-surveillance based SCADA networks were prototyped for use along paths, and they must either be installed with dedicated short-range communications in intelligent transportation systems or monitored with devices such as those with RFID applications. The inclusion of interior dual-surveillance based SCADA networks should be considered. In this paper, such systems are proposed for Kaohsiung, where air and sea port services should be integrated for the regional logistics-related industry.

Restricted views of objects for vehicle drivers are a potential cause of concern. Similar to vehicle drivers, security and traffic managers require unhindered views of both sides of the vehicle. In addition, communicating with the driver or vehicle and providing clear information related to three-dimensional (or both sides of the vehicle) real-time factors would reduce the risk of incidents or accidents. Invisibly, compromised wireless communication data can be more easily identified by comparing the difference among signals acquired through parallel sequences of location-defined sensors. In particular, using monitoring devices in pairs can cooperatively provide clearer images through correlated double sampling; such cooperative operation can effectively enhance information integrity and promote mobile commerce.

In emergent RFID applications, dual surveillance can adaptively offer detection availability for preventing invisible interference caused from metal or other materials together with the information transmitted by or to vehicles (i.e., the shielding of or interference with radio information by metal or water). Hence, the use of dual surveillance, for collecting information on visible and invisible images, is suggested for the aforementioned paths.

Communication is essential for airports. To improve airport services and security, network prototypes such as SW(m, n), which can provide detection availability, high maintenance efficiency, and optimal degree to establish a dual surveillance system, offer high robustness and data integrity for cellular communications as well as wireless and heterogeneous SCADA networks. Radial ring spider-web configurations were prototyped for interference-free cellular telecommunication and adaptively applied to develop main-area SCADA networks composed of dual-surveillance based subnetworks along paths; the advantages of the SCADA networks include favorable fault tolerance, high parallel processing capability, dynamic authentication and authorization, detection availability, and countering capability for the multipath effects of wireless communications. Moreover, such configurations can offer integrated response capabilities even after the SCADA networks of two paths have been destroyed.

The cube-connected-cycles network can be easily processed for parallel computation in the available hypercube-derived algorithm. Hence, probe with a unit of sensors are designed as a unit-node in a hypercube-like configuration; the link of sensor nodes is lessened to be three. Such probes can be modularized. Its possible-length parameter can be used for systematically verifying processors connected to the network and designing processors for the network to be deployed within a reasonable size of the area, which is assumed to be the water area of the harbor.

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