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Enhancing Digital Connectivity, Smart Transportation, and Sustainable Energy Solutions Through Advanced Computational Models and Secure Network Architectures

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Abstract

Smart cities are rapidly rising to confront numerous challenges, including the need for enhanced digital connectivity, better management of public utilities, faster transportation, and energy cost savings through sustainable solutions. In these respects, developing smart cities demands innovative informational and networking technologies, secure and energy-efficient communications, as well as computational infrastructure for data analysis, forecasting and optimization. Advanced computation and graph analysis models can predict various city campaigns and help authorities make better decisions regarding city expansion and control setup in a citizen-friendly manner. These models should be prepared for large cities so they can forecast the situation under a continuous or step change of conditions. However, such models require a substantial amount of data and intensive computation in the storage and operation stages, which is not aligned with a utopia of real-time analysis for large cities. Developing network modeling and formulation procedures influencing data gathering and modeling from city infrastructure concerning urban mobility and spatial data networks will help improve efficiency in computation and data collection. Such networking models must be based on intelligent techniques such as spatial filtering and multilayer graph analysis. At the same time, an approach is to improve network infrastructure by merging advanced technologies, open-access, and programmable equipment, aiming to facilitate the establishment of novel testing city lab conditions of complex network design, optimization, monitoring and control solutions. Employing various smart cities data mainly in the form of graphs subsidizes the knowledge inputs of machine learning. Proposed innovative frameworks for the construction of non-invasive, adaptable, and mature real data facility beacons can sponsor experimentation in the real-world of innovative urban networking solutions. Experimentation with such beacons will make it conceivable to assess the performance and operational sustainability of urban network drones. In such a way, a virtuous cycle of data-driven intelligence in networking solutions will combine simulations and real urban data. Smart cities bring together various information and communication technologies to increase public activities, minimize utilities expenses, and more efficiently deliver inhabitants with facilities such as healthcare, transportation, and energy.

Keywords: Sustainable, data-driven, secured, process modeling, optimization, and communications, discrete event, and multiobjective nature of smart cities, green, Internet of Things, genetic algorithm, simulation, immediate access to network, Smart and connected communities.

1. Introduction

In the near future, advancements of electrical grids will devise an increased number of smart devices to satisfy customer needs. These resources include smart meters, smart cars, renewable generations, energy storage systems (ESS) and automated intervention apparatus. A hybrid network comprising wired and wireless connections, so-called cyber-physics-system (CPS) to monitor and handle the complexities emerging in such scale environments, will be established to realize the advanced computing paradigm which correlates human intelligence with cybernetics intelligence. The accompanying big-data processing, analysis and control will be the breakthrough for future electrical power networks, leading to an intellectually manageable power system. The vitality of smart and connected communities is nowadays emerging globally to adapt to the upcoming infrastructure challenges. A nation-wide community framework is permeating with a target of enhanced transportation services, intelligent urban designs and living aid, catalyzed via the continuous financial support raised from the Smart City Challenge grant.

The steady demand growth and the novelty of infrastructure are envisioned with the development of smart and connected communities, directly affecting the next-generation advanced computational models, secure network architectures, secure data management and associated protocols. Aiming to safeguard and optimize the operation, strategies of secure network architectures and secure data management will be proposed. To defend against prevailing cyber-security attacks which are launched from competitors, activists and tech-savvy individuals, security measures in the CPS will be devised and their outcomes analyzed. At the same time, topological analysis of attacks on the physical infrastructures will be conducted so as to avert critical impacts on society, such as water poisoning, blackouts and road congestion. The scheduling, routing and power protection schemes of secure data management for the smart devices will be put forward.

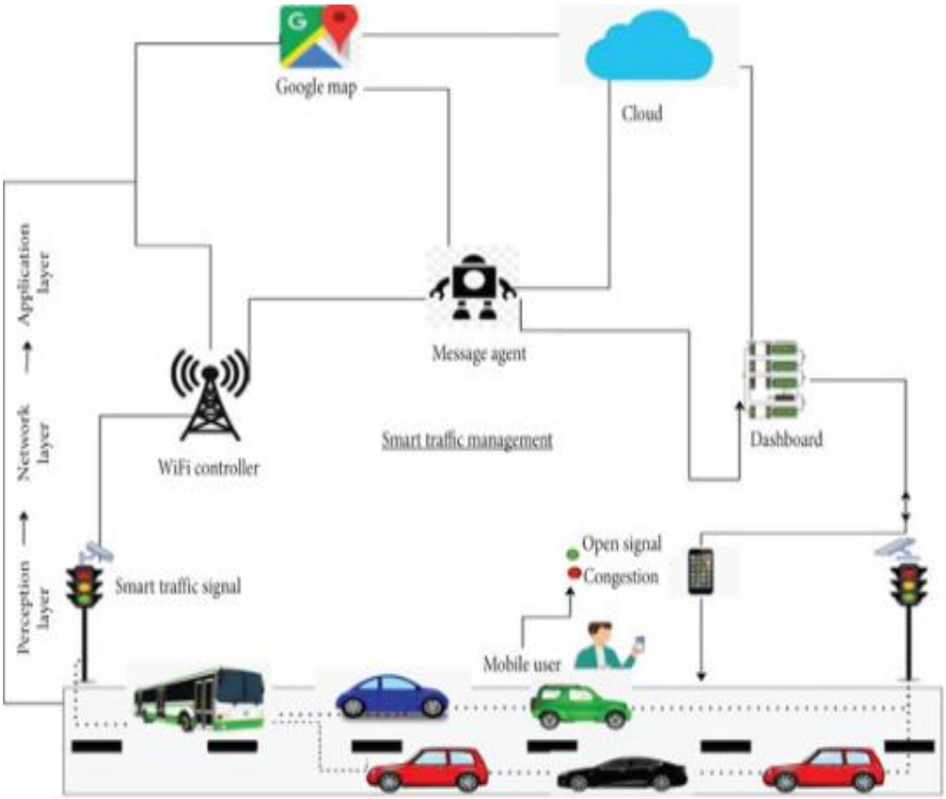

Fig 1: Smart Traffic Management System

1.1. Background and Significance

Digital connectivity has revolutionized our daily lives from online social interactions, business, and education to health, and has streamlined global trade and financial systems. On the other hand, the demand for reliable energy resources is surging to facilitate digital applications, which have contributed to energy access disparities in the developing regions. It subsequently exacerbates environmental challenges as significant greenhouse gases emissions are produced due to the high energy consumption of data centers. To mitigate this, advanced analytical tools, including computational models and network architectures, are proposed to enable more coordinated and intelligent approaches. For that purpose, smart grid technologies and renewable energy sources are integrated into energy solutions to enhance the performance and resilience of the system. In that framework, a wide range of energy systems, digital networks, and transportation infrastructures are considered as interdependent networks that constitute a connected and smart city. The performance and resilience of this network are studied via a computational framework involving graph theory, machine learning, stochastic modeling, and optimization. The results demonstrate the effectiveness of the proposed strategy. They provide several policy implications for urban planners and city managers.

Transportation systems represent the human-made systems that enable people and goods to travel from one place to another by involving several modes, such as cars, trucks, and buses, along with roads to navigate on. It also plays a crucial factor for the economy and social life, defining shapes and cultures of cities and societies. However, those systems still contain several ongoing challenges, such as large and growing urbanization rates, standard expansion and increasing demands for freight transportation by the prosperity and human mobility itself. Thus several questions have been done in this research, such as how to optimize public road gaps for maximum restitution, minimum cumulative public travel time, and maximized network efficiency under the primary demand assumptions on a city in the Francilien Urban Community; how to prospect system pect peaks which respects regular and recurrent intervals. Herein, a methodology proposal for a new comprehensive, open, and easy-to-use computational framework which can shed light on these challenges and questions, considering every road in a given city. A real-scale case study concentrates on the capital of Turkey, particularly. The results suggest generally adopting a uniform opening standard for the IMSI so that it is utilized optimally while securing equitable restitution patterns around the city.

Equ 1: Enhancing Digital Connectivity

$$\text{Maximize: } C = \sum_{i=1}^{N} \log_2\left(1 + \frac{P_i}{N_0 B_i}\right)$$

Where:

- C = Total network capacity (bits per second)
- P_i = Power of the i-th transmission
- N_0 = Noise power spectral density
- B_i = Bandwidth of the i-th channel
- N = Number of communication channels

2. Digital Connectivity

The European Commission published a plethora of policy proposals to improve road safety, reduce air pollution and greenhouse gas emissions, as well as enhance the competitiveness in the automotive, mobility and energy sectors. A three-layer open-network architecture is envisioned, in which roadside units (RSUs), edge-cloud computing centers, service providers (SPs), cellular networks (CNs) and Internet can form an interconnected backbone with a tussle-free free flow of information, data and money. It is described how this vision can be implemented using state-of-the-art commercial off-the-shelf technology deployed in a field trial setup in the US.
These trends and technologies will foster a new era of connected and autonomous vehicles (CAVs), eco-friendly green vehicles and advanced road infrastructure management, heralding a radical transformation in mobility, roadway use and energy consumption. To complement these policy changes and technological advancements, a digital infrastructure investment proposal targeting the deployment of current and next generations of vehicular-edge-cloud computing, two-ray ground-wave radios and Long Term Evolution (LTE) and 5G cellular systems is described. Furthermore, it is described how a three-layer digital infrastructure can set the stage for the co-existence and synergetic deployment of infrastructure- and network-based mobility, energy and environmental management services.

2.1. Current Trends in Digital Connectivity

The European Commission emphasizes the need for safe, clean, and connected mobility. Advanced computational techniques have been transforming the transportation, energy, and communication sectors through the development of smart models and applications. In the BIG DATA research group, efforts have been made to design advanced computational tools for enhancing digital connectivity, smart transportation, and sustainable energy solutions. In digital connectivity, the gradual transition from landline to wireless network and beyond results in an increase in users' reliability on the Internet, social media, and mobile services. In the context of developing countries, this transition is more noticeable. Such types of digital sources motivate researchers to investigate various economic, social, and security issues with a particular focus on connectivity. Together with internet connectivity, wifi routers, and mobile apps, the new commercial service in an Indonesian intercity train did not function adequately prior to the pandemic. In this situation, internet connectivity issues and the potential effect of the passenger network on transportation planning have been explored. Recent perspectives on the impact of autonomous vehicles (AVs) are changing significantly. An analytical procedure has been proposed to investigate the under-equilibrium function of mixed traffic flow consisting of AVs, conventional vehicles, and buses, e.g. the effect on fuel consumption and pollution. An optimality in terms of permissive AV penetration rate has been observed. Restrictions are imposed on number of vehicle re-optimization, and periodic shipment is replaced by rail ferry; thus configuration changes in transport policy will change the socio-economic condition resulting in re-allocation of demand in terms of freight and passenger. The formulation backing the good network has been developed most flexibly and backed the worst allocation of demand. On the other hand, the SCI on the worst node has the highest demand. Cybersecurity attacks have been addressed, where vehicles are likely to be misinformed by the corrupted infrastructure signals or by a false base station. An efficient network system has been presented for urban and suburban city types. The implications of connected vehicle (CV) technology on transportation planning are investigated, and possible subjects and importance issues are found. Finally an IoT based CV data warehouse architecture is proposed. Data pre-processing including data alignment and data cleaning are used to resolve the receiving time difference of the data caused by vehicle's communication protocols. Furthermore, a green wave CV algorithm is developed in the next time period that can maintain the speed for a green wave scenario for the entire traffic network. Meanwhile, an ensemble-based trajectory clustering algorithm is involved in cloud processing to classify traffic states considering the traffic flow of the other lane. The demand for society and railway safety needs to increase which could cause a decrease in reliability because the greater the demand for passenger trains, the less train paths are available. Nevertheless, this is the plus point for operators wanting to decide on better service. The flow of time particulars is vital for this process and must be chosen very accurately, and strategic, top speed and times for dynamic planning and process-driven approach with improved viewing of data and electronic files for analysis are evident. The traffic state estimation is based on past congestion. Spatiotemporal traffic big data is used to estimate the real-time traffic state at the network level. A linear light-CNN model is proposed to explore spatiotemporal traffic correlation, which applies the adaptive and multiscale kernel to analyze the correlation with graph structure for noise immunity. The progressive growth of vehicle-to-everything communications systems enable vehicular devices to access different services. A vehicular cyber-physical system model is proposed with a focus on navigating informative services, life-saving applications especially on demanding environmental conditions. In scenario four an artificial jammer is introduced to obstruct the accessibility to these emergency services provided by the infrastructure. Centers deal with the power iterations method' measurement where the network's occupation time and the amount of time captured are the first time, to form the Taylor series by expanding the network's traveling time. Spectrum monitoring refers to procedures for the discovery and management of spectrum usage, which plays a pivotal role in promoting the efficient operation of radio spectrum. Spectrum resources are highly scarce owing to the intensive demands of various wireless communication systems. To cope with the demand for the rapid development of future wireless communication systems, such as 5G, spectrum sharing is considered as an effective solution. Detective approach is an intrinsic advantage over the signal characteristic method in detecting arbitrary signal types. Cognitive blockchain wireless network architecture has been proposed to dynamically allocate and manage spectrum resources, ensuring that the blockchain devices can access the best available resources and meet the diverse groups for QoS requirements. Persistently, spectrum management must enable fair and just use of radio frequency spectrum resources within the regulated area. Passive Drone Detection based on Automatic Identification Systems signal sensing via a sophisticated algorithm is proposed, which price minimum false alarms. Another key research work category within the point-to-point communications related to connectivity and addresses the issues of inter-vehicle communications of V2V and from vehicle to network infrastructure of V2X. An improved connection context algorithm is proposed for the data collection between vehicles and roadside units in urban scenarios. The path planning algorithm criticizes Lane keeping, sensor and actuator cascaded setup problems, and simple rules postulated to the intelligent car. Documentarian highlights that the limitation is Mental effort and User distraction caused by working with the GMM on the paper is a typical FT syndrome found in scammers' condition with LBS. However, some of the limitations of exactness are not explained clearly regarding each real experiment. Researchers document there are limitations in human error processing data from RTK-GPS receiver to UTM for Trajectory generation. The deadlock paired vehicle pathway persists under all different scenarios due to no correct error spill really obfuscating the exact road to proceed. But other prominent scientists as generally addressing with an expert algorithm and observations be considered carefully, this topic needs further exploratory advances. Detailed and incremental analyses introduce results that can furnish additional insights into how far thresholding can disentangle emergent behavior in the case of traveler and Land.

2.2. Challenges in Digital Infrastructure

Digital infrastructure is seen as a critical complement to the physical infrastructure in enhancing mobility, improving safety, minimizing environmental degradation, and achieving sustainable urban development. How to finance and operate digital infrastructure has emerged as a key challenge facing researchers and planners. Considering that digital infrastructure deployments have traditionally been funded by private telecommunication firms, it is important to identify a proper strategy for cooperation between public agencies and private firms. However, the importance of digital infrastructure in enhancing the effectiveness of the investment in roadway infrastructure necessitates a more proactive role for public agencies in the design and in certain aspects of the deployment of such facilities. Digital infrastructure specifically for transportation/connected vehicle applications from the side of public agencies. Five fundamentally differing corporations around the globe today.

Experience demonstrates that different agencies or other stakeholders involved with transportation / CV technology deployment will have different perspectives as to who should have the right or duty to commit capital in, perform operations and managerial functions on, and/or assume maintenance responsibilities for the digital infrastructure. Discussion of experimentations, its results, and policy lessons. A department that leads in the guidance of the intelligent transportation systems efforts of an entire country. Today, the required policies must be executed and the necessary traffic and transportations are wide pursuit of road safety, mobility improvements, congestion reductions, as well as environmental improvements. This discussion aims solely to address the digital rollout part of that, although of course digital infrastructure must be provided shortly thereafter. Beginning in the mid-1990s, the authorities of a certain southwestern-style state in North America investigated how to potentially use digital communication, sensory, and informational screeds to enhance the state's transportation activities and service distributions by motor vehicle. An initiative in which there are no commitments to any economically or organizationally material digital investments yet. However, such a large number of tactical, operational, functional, operational matters generated by those initial requirements, studies, and investigations. Also seemingly unprecedented concerns are expressed in written communications among important market participants about the legal implications of prospective and potential digital infrastructure for surface transportation activities.

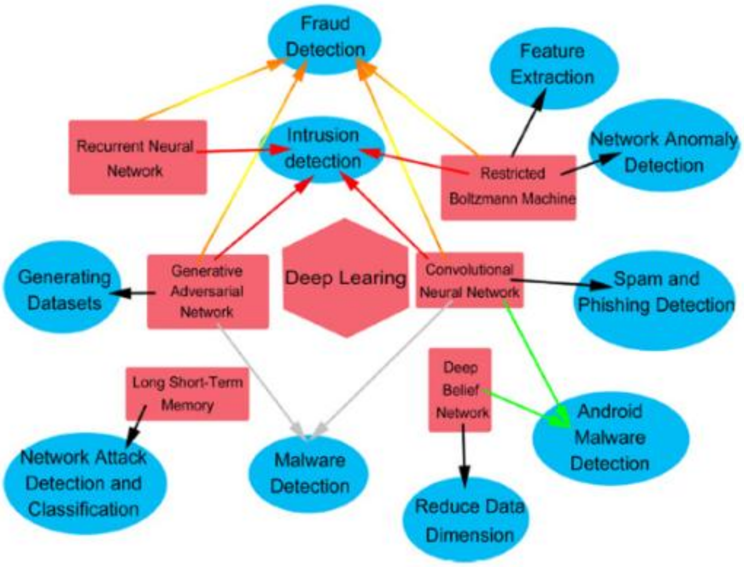

Fig 2: Technologies used, leading challenges and future recommendations

3. Smart Transportation

Today, 1.3 billion people worldwide use Intelligently Connected Vehicles (ICVs) in some form. In 2025, this number is set to double, resulting in high demand for the rollout of various Digital Mobility Services (DMS) that deliver new customer features. With Enterprise IT moving to the cloud and the Internet of Things (IoT) connecting myriad previously isolated systems together, there is a growing risk of cyber-attack. Legal responsibilities around vehicle cyber-security are currently ambiguous, with vehicle manufacturers under pressure from various national and international standards organizations to secure their onboard Electronic Control Units (ECUs) against cyber-attack. Finally, cyber security is only as strong as the weakest link, so if OEM security protection is bypassable, devices that connect to unsecured ECUs could be an open door for attackers. There remains a need for effective security mitigation strategies that can a) protect consumers and their vehicles from remote cyber-attacks delivered via Internet connected infrastructures and services, and b) reduce vehicle and road network vulnerability to connected attacks. There is a particular concern for customer privacy about ICVs and DMS; too much location data could allow stalkers to track people, or provide 'time of greatest vulnerability' information around known excursions. Automotive Telematics Applications are growing in number and sophistication each year, with more vehicles coming pre-fitted with some form of telematics system. These systems can record driving behavior data, as well as having the ability to send and receive SMS texts and other network messages. Telematics data have already been used in a variety of insurance schemes and road pricing models, and regulatory or self-regulatory frameworks are increasingly requiring the permanent recording of certain data by vehicle systems, creating a concern for those uncomfortable with the idea of a 'black box' in their car that can be interrogated by third parties. The latter assumes that privacy-concerned users want as little data stored about them as possible, and so effectively de-coaching the data is a valid strategy, although difficult if still requiring a useful system analysis. Low-complexity encryption brute-force attack mitigation; the work is focused on a number of privacy oriented mitigation strategies that include both statistical data coarsening and device security. Statistical coarsening refers to various methods that aim to reduce the time resolution and/or fidelity of attackable datasets, making them unsuitable for a comprehensive analysis. Device security is a term used to cover a range of security mitigation strategies designed to protect against reverse engineering of a device, illicit data extraction and device replication. Land Transport networks are the predominant means by which most passengers travel, be it car, bus or public transit. Smart Transport Systems offer the potential for better quality information about travel networks, allowing for more adaptive routing for the same data traffic, or better dynamic load balancing of information flow to particular nodes or across links. A survey is presented covering domain-specific smart transport applications and associated sensing technologies. Many of the wide range of data sources currently in use are 1) quantitatively profiled, and 2) applications presented that use sensed data, and their associated benefits and challenges discussed. Smart Cities; the rapidly increasing demand for urban passenger travel, coupled with the need to reduce its economic and environmental cost, has made it a crucial content for smart cities to embrace and invest in. Any

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process that changes the way that people move through such an environment, such as pricing, enforcement or layout, directly impacts the demand and capacity of the associated network. At the same time, the physical realization of such networks, be it road or rail infrastructure, also shapes travel behaviour.

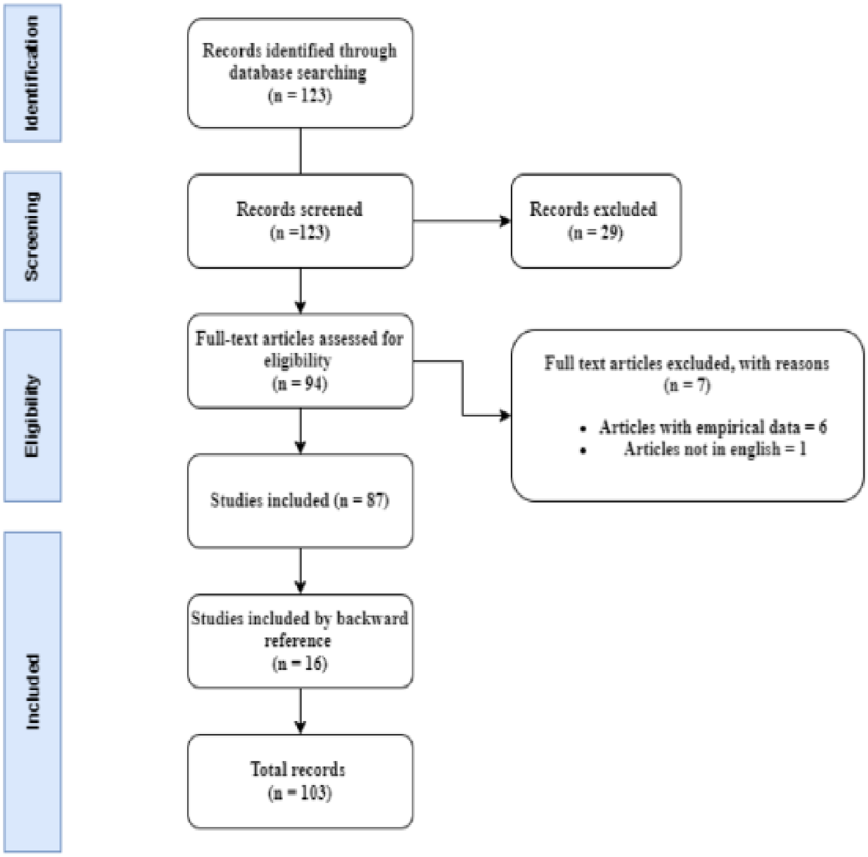

Fig 3: Smart Transportation

3.1. Overview of Smart Transportation Systems

The smart city is a terminology referring to the holistic approach and incorporation of various facets of informatics to enhance livability, sustainability, and workability within a city. This aim is achieved through carefully developed and numerous cybernetic systems within the various domains, such as digital governance, smart transportation, etc. In the context of smart cities, sensor networks and unprecedented levels of informatics can provide a detailed overview of transportation processes, resulting in more efficient and effective coordination for moving people and goods across the urban environment. It is crucial to wisely influence and manage the transported flow by utilizing all the available means. This statement covers public transportation means, such as buses, trams, or subways, but also individual transport, such as cars, motorcycles, or bicycles. There is a specific difficulty in comparing traffic systems against other networked systems, as the entity (vehicle) within which the requests are moved is substantial in size and moreover composed of numerous separate elements. Conversely to data networks made of packets that are disjoint units, vehicles interact when moving over the road network and support the evolution of the traffic states in a complex way. Due to these features, to which one should also add the roots in the physical world, the approaches to traffic modeling cannot be directly transplanted from the already developed theory around data networks. On the other hand, the sudden progress in sensor technologies, informatics, actuators, and artificial intelligence is producing a radical change in the approach to the transport systems management and paves the way for the upcoming completely new paradigms.

3.2. Impact of IoT on Transportation

As smarter and smarter cities are being created, state-of-the-art, futuristic transport systems are beginning to be designed. These new systems promise to improve the mobility of road users, the operational efficiency of the transport system for the agency, and reduce overall traffic congestion. Automakers and infrastructure funding agencies are discussing creating a nationwide deployment of Connected Vehicle (CV) technology in the United States. A significant goal of this envisioned system is to establish vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) alarming protocols such that crashes

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can be avoided. Mixed integer linear programming and optimization methodologies are used to formulate traffic system control problems. Vehicle lane-changing behavior is modeled and integrated with longitudinal vehicular dynamics to forecast the impact of real-time parameters on the vehicular trajectory. This model is used to help resolve a model predictive control problem that optimizes traffic system efficiency and safety functions. The Barabási-Albert network model is used to generate, develop, and analyze synthetic systems with a prescribed scale-free network topology. Moreover, the transmission time of two messages in a network is calculated via a diffusion equation that models the progression of the influence of the first message broadcast over the network. A general framework for analyzing the temporal effectiveness of directed message delivery between an arbitrary sender and receiver on a scale-free network topology is derived. Together, these tools allow us to explore the parameters of a network system that benefit from functioning inter-vehicle communication the most.

Equ 2: Smart Transportation

$$\text{Minimize: } F = \sum_{e \in E} c_e x_e$$

Where:

- F = Total flow cost
- c_e = Cost (time, energy, or distance) for using edge e
- x_e = Flow over edge e
- E = Set of edges (roads or transportation links)

4. Sustainable Energy Solutions

The maturation of the distributed energy resources (DER) technologies has been identified as one of the pivotal keys to unleash the transition towards the so-called Energy Web landscape. DER devices provide the opportunity to improve the grid performance, the energy efficiency, and the quality of energy services. However, the widespread integration of DER units poses novel challenges both from an operational and from an economic perspective. In the emerging DER scenario, the traditional business models and the incumbent energy market design need to be reviewed. From the technical point of view, the massive integration of distributed generators, storage devices, and controllable loads in the grid raises critical control and optimization issues. Such devices have to be coordinated for fulfilling not only local, but also global grid objectives. The advanced computational modeling of electric grids is thus crucial to design and validate efficient and scalable strategies for the DER deployment and operation. Here, the mapping of the physical grid onto a complex network approach allows investigating the mutual interdependencies among the spatially distributed DERs and the high-voltage grid network. Regarding the economic facets, it is of critical importance to design well-suited market architectures able to provide equitable access to the new energy markets for both incumbent and new entrants. The distribution-level market platforms have to be set up in such a way as to conciliate the global network's reliability and security with the achievement of efficient energy transfer. The possible emergence of price spikes and network congestion has to be carefully evaluated for safeguarding the fair competition under stressed operational conditions. For these purposes, secure network architectures aim at integrating computational vulnerabilities within the network structure by means of a minimum increase of additional hardware and communication resources.

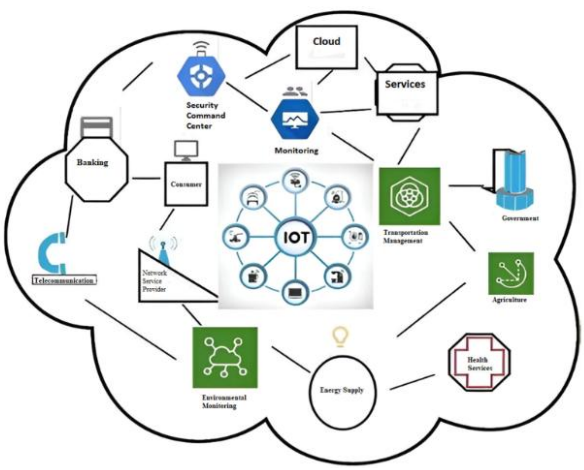

Fig 4: Sustainable Energy Production

4.1. Introduction to Sustainable Energy

Balanced development is central to the Post-2015 Agenda's overall goal to end poverty and bring prosperity to all. Despite the recent pick-up in economic growth in many countries, progress has been uneven across and within countries, and the resultant inequality has been high. A special effort is needed to address significant infrastructure gaps, growing income disparities and increasing environmental pressures. The increase in digital connectivity creates opportunities to overcome the existing disparities and deliver basic services, including mobility, health-care and education, more efficiently. Developing advanced computational models on top of robust telecommunication networks can help sustainability by implementing optimized network structural design. This research aims at constructing a novel approach to accomplish the goals described above.

The project focuses on networks carrying flows of main current interest, aiming for developing computational models to design network topologies optimized for advanced goals. Two different areas have been identified for such investigation. The first regards the development of smart transportation networks at city level. The increasing concentration of world population in urban areas, together with the meeting of energy needs, concurs in the exacerbation of heavy traffic conditions. The implementation of public transportation networks helps alleviate congestion and pollution though, for instance, double-edged effects between network-oriented economy and ecological aspects should be considered. These aspects go beyond a gut feeling and should be the object of dedicated computational models. The second research field regards the evaluation of the expansion of digital connectivity towards the remote field. This reiteration is important for setting down the necessary groundwork and attacking the problem with renewed insight. Given a distribution of sites of a certain type, it is desired to construct new locations of the same type in such a way to minimize the average separation among sites of different type. Moreover, secure network architectures for isolated locations, requiring economies of scale, are important in emergency cases. With transport cost playing a relevant role, constant rational decisions should be undertaken to optimize network degree of connectivity, enhancing the health of all individual nodes and average system-wide performance.

4.2. Integration of Renewable Energy Sources

The expansion of the Internet has initiated the development of new services and devices, often items that are a part of the Internet of Things. The digital connectivity of devices is based on direct communication, which is often driven by a smartphone. Digital connectivity can meanwhile induce services for security purposes as well. In this manner, visitors that are living far from cities could facilitate their parking and visiting the center through the digital network connection. Given that search queries will be directly connected to the parking sensors, thus showing where available spaces are located. The evolution of electric vehicles has been remarkable during the past few years. A series of car producers have announced a large portion of their automobile fleets will be electrified in the near future. The motivation behind the transportation rearrangement to electrified means is energy based, representing a more effective way of using energy for road transport. On a European level, the effort for expanding the EV market and use is based not only on the energy merits, but also supporting the European market of the car industry. The support will be also based on offering a scope of infrastructure, by creating and expanding the infrastructure and ensuring the operation of charging stations. Connected to the issue of parking stations and the support of charging, one of the services that could be developed is the reserved parking station for EVs, with the location of the charging stations to be reserved exclusively for the EVs. While an EV is parked and connected to a charging station, the parking duration will be attached. In this case, the digital connectivity must recognize the exact time the vehicle is parked, and in case the vehicle remains immobile after the attached reservation time, the connected parking meter shows that the vehicle is parked in the wrong spot. Collecting drive data from the connected vehicles could reveal useful information that would allow for better adjustment and management of the transport system. With the expansion of the digital connectivity of a large part of the vehicles, the collection of useful data from vehicles could permit for better coordination and advancement of transportation planning.

5. Advanced Computational Models

Smart and connected communities (SCCs) could revolutionize the way people carry out their day-to-day activities in urban areas through the improvement and integration of transportation, communication and energy infrastructures. The backbone of this transformation is the efficient provision of these three basic services and thus, being able to understand the interdependencies better will be crucial for their sustainable operation. Considering modern cities, the substantive growth in the number of existing and planned sensors has fostered the possibility of developing complex simulation models, capturing a wider number of dynamic aspects and aspects in higher detail. In this context, a new flexible and scalable multi-layer, multi-block, multi-agent (3M) approach is proposed to capture the complex dynamics of several interconnected domains. In order to test the benefits of the proposed methodology, it is demonstrated how it can be used to model the interaction of energy, transportation, and communication systems in SCC. According to the developed approach, corresponding open source Modelica models have been made publicly available. Two newly developed models are used in one out of three case studies, combining a dedicated, user-friendly look at the consumer perspective. The benefits of these models are underlined in comparison with existing tools. Finally, three case studies are applied to a real test bench, the urban area of Groningen, in order to see how exchange cost-benefit information between different domains can improve the overall performance of the community. Modeling the activities of a smart and connected community, i.e. an actionable policy plan design, requires a significant know-how of the employed models and a considerable amount of computational resources. Those limitations are tackled by proposing a new model taxonomy and an efficient, extendable meta-model architecture. Potential benefits are demonstrated using a three-domain community equipped with a set of solutions, modeling/optimization-driven decision support tool for the community manager, and a demand-side application. The proposed modeling framework is applied to a relevant case study exemplifying a city/region-level smart, connected community (SCC) operation.

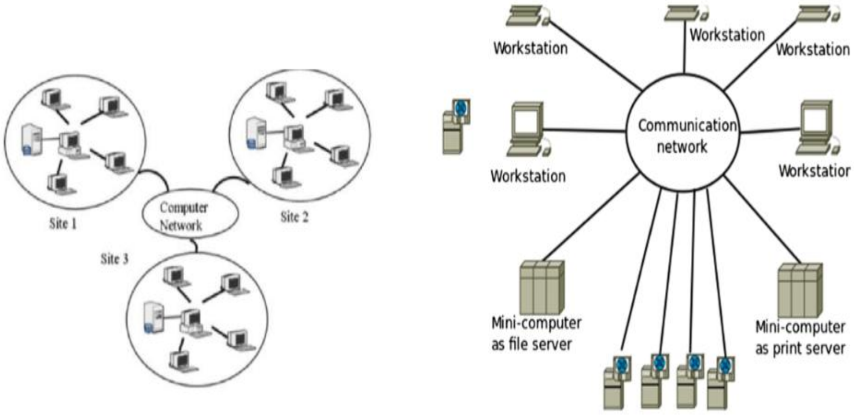

Fig 5: Computational Models

5.1. Machine Learning in Connectivity and Transportation

Technological advances in wireless communications and smart systems are making possible a new capability to propagate connected and mobile architectures. Applied to smart transportation, the latter transforms into parallel and concurrent action between a steadily increased number of entities, such as vehicles, travelers, and traffic infrastructures within urban, metropolitan and land-use settlements. On the other hand, the utilization of sustainable and renewable energies to power up networked connected devices or systems increasingly aims to substitute or complement traditional diesel-powered generators. Making both, the aforementioned, potential revolutions achievable, requires novel and possibly disruptive methodologies and technologies. These comprise advanced computational models for predicting future states derived from observations and interventions, realization of these models through connected and optimized networks supporting advanced security and privacy architectures.

Recent research has focused on machine learning methodologies applied to a wide variety of scientific research domains. An integration of networked computational models and resource-aware learning paradigms enhancing predictability and realization of state estimation have been closely examined. A broad enough analysis of similar applications is performed in the transportation and connectivity domain, suggesting the formulation of a distributed and autonomous architecture proved via machine learning models. The aforementioned architecture is defined over energy systems and can be applicable to suitable wireless connectivity and transportation systems. Prominent machine learning models featuring K-nearest neighbors (KNN) and random forests (RF) are adjacent to the smart transportation system, operated in parallel and supporting a rich set of communication means, such as Digital Enhanced Cordless Telecommunications (DECT), Global System for Mobile Communications (GSM), and wireless connectivity among vehicles.

As an effect of the information exchanged, vehicles and the surrounding infrastructure estimate the future behavior of other travelers and vehicles and take pre-emptive, pre-triggered or autonomous control actions towards path optimization, absolute speed, and safety satisfaction. A parallel set of machine learning models close to communication infrastructures support connections among devices through protocols and networks and manage a proper and possibly fastest frequency carrier for each wireless connection, while under numerous adversarial actions.

5.2. Simulation Models for Energy Systems

Recent projections show that approximately 60% of additional energy demand by 2060 will be in cities. Therefore, local energy management is critical for smart cities, in which enhanced digital connectivity and smarter control strategies can optimize energy usage. Due to the growth of information and communication technologies, future smart cities are

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envisioned to be smart, i.e., equipped with many cyber controlled features in different domains. In particular, endowing them with smart transportation and energy features can notably improve the quality of life in cities.
Most of the latter scenarios are underpinned by advanced computation and smart communication among components, as well as by appropriate monitoring and control strategies. To design and optimize them, there is an increasing need for suitable testbeds. Since dealing with real systems can be preclusive due to high costs and time constraints, it becomes indispensable to resort to numerical models. The use of such models permits both the investigation of potentialities and shortcomings of a system under consideration and the design and validation of proper control strategies.
In recent years, computational techniques allowed the improvement of the accuracy and realism of energy systems' modeling, thus playing a crucial role in examining the effects of the integration between energy systems and other fields. In particular, energy models can be designed to have a proper trade-off between accuracy and design effort, depending on the considered system and the addressed problem. Usually, models can be designed at different abstraction levels, from low detail levels (or aggregated models) providing fast-to-solve and easily interpretable solutions, to high detail levels (or fine-grained models) capturing more of the physical reality of a given system. Among these models, concepts rooted in thermodynamics and graph theory have been successfully combined to design frameworks able to capture the overall energy fluxes of Unconventional Energy Systems. Besides simulation models, networking and control theories are other available frameworks able to cope with the interconnected nature of the systems at stake. The authors discuss the possibility of designing, tuning, and testing proper control strategies, thanks to co-simulative tools. Their approach relies on the widespread discrete event (DE) paradigm and on the advantages provided by open-source technologies.

Equ 3: Autonomous Vehicle Routing

$$\sum_{j=1}^{N} x_{i,j} = 1 \quad \text{and} \quad \sum_{i=1}^{N} x_{i,j} = 1 \quad \forall i, j$$

Where:

- Z = Total travel distance for the AV
- $d_{i,j}$ = Distance from location i to location j
- $x_{i,j}$ = Binary decision variable, 1 if the route goes
- N = Number of locations to be visited

6. Secure Network Architectures

The interest for secure network architectures is growing because of the digital connectivity advances in the Internet of Things (IoT), exploiting connection of numerous gadgets with processing and transmission abilities, and the augmented use of cloud/edge computing services. This combination is giving way to the enhancement of smart services and mobile applications. The use of cloud processing for smart transportation solutions along with the implementation of sustainable electric-powered vehicles is boosting the number of connectivity-oriented services that are based on the dependency of cloud services for their control and operation. Consequently, issues of mobility, cloud availability and focused DoS episodes have been more frequently recorded.
Proper safety mechanisms are required for effective key delivery/scaling since public infrastructure and hardware protected terminals are not always applicable. Research efforts to tackle this issue are active in the area of mobile or portable computational gadgets. Mobile devices and mainly small cell base stations are becoming increasingly important for secure network access. Last generation of mobile gadgets include computational power and software-defined system integration, which allow for small cell applications. Since the radio front arrived like a portable piece that can interact with a versatile base band, it is simple to see that those gadgets are now becoming LPNs.

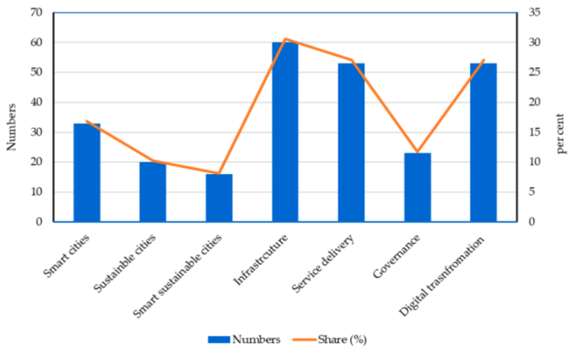

Fig : Relationship between Digital Transformation

6.1. Importance of Security in Digital Connectivity

This paper focuses on the urgent need for cybersecurity measures to be proportionate to the capabilities of the organisation, and this should be achieved by a mix of matched technical measures that are informed by socio-technical security modelling and simulation. It benchmarks the UK's National Cyber Security Strategy, and discusses government interventions to improve the use of security modelling and simulation in the Critical National Infrastructure. The discussion is drawn from a policy note produced for policymakers and presented at an online workshop on April 16. Participants included representatives from critical sectors, government officials, research funding bodies, and academics. It aims to raise awareness of THE importance of using robust cybersecurity modelling and simulation (M&S) techniques that are grounded in an understanding of a wide range of social and technical security factors/pitfalls.

6.2. Frameworks for Secure Network Design

Concerted efforts worldwide are being made to promote both economic advancement and the United Nations' Sustainable Development Goals. In this context, the Fourth Industrial Revolution encompasses advances in machine learning, the Internet of Things, 5G and 6G networking, quantum computing and communications, as well as blockchain and secure multiparty computation. This Revolution will be brought about by technological solutions designed to optimize and converge the physical, digital, and biological domains. It will provide opportunities to enhance digital connectivity, smart transportation, sustainable energy solutions, educational outcomes, food distribution, and waste management, as well as to forestall pandemic threats.

To harness these opportunities, comprehensive planning must be combined with deployment of innovative technical solutions. Advanced computational models and secure network architectures serve as key enablers of transformative growth and inclusive development. Investment is needed in these sectors for long-term financial well-being, as they can provide a basis for a coordinated approach to advancements across multiple fields. High-performance abstract models, before their deployment in systems tailored to specific conditions, are being prepared to derive effective guidelines for planning appropriate infrastructure, regulations, and investments. Four concrete models of future systems for enhancing digital connectivity, smart transportation, and sustainable energy solutions, responding to requirements for revolutionary progression in these areas, are delineated. The discussion refers to quantum-ready trusted nodes, which process classical and quantum data traffic on edge and access levels that have been allocated classical interfaces to the core, transit data switches with classical interfaces that connect otherwise quantum-access points, and virtual quantum network services. The network supporting internode EGP has, beyond contemporary quantum networks, no connected genuine quantum nodes, actual EGP being between classical repeater nodes.

7. Conclusion

With explosive urban growth, quantifying and predicting the responses of complex infrastructure systems to resilience enhancement operations and challenges using traditional physical experimental methods become impractical – considering their high costs in both time and resources. Accordingly, in recent years, researchers have been recognizing the potential of advanced computational models and simulation tools to facilitate this goal. Moreover, with advancements in technology, the arrival of smart cities is almost at hand. Innovative approaches are being introduced to handle the growing need of smart energy, smart transportation, and smart communication, through different modeling methodologies. To take examples, the integration of renewable power sources, energy storage devices and smart loads/batteries in the power system paved the way for smart energy. Similarly, the use of real-time traffic information using sensors, analyzing data, developing signals, and controlling traffic lights, resulted in smart transportation. Finally, adding more computing units to some traditionally-used devices enables bidirectional communication between sensors and data centers, resulting in smart communication. There is also a growing need for efficient interconnection between complex infrastructure systems. Recently, the concept of Interdependent smart and connected communities is being advocated in order to focus on the future population explosion in urban areas. Above discussions reveal limited scope and associated challenges. A high-quality platform and systematic framework are needed to explore the potential benefits in resilience of advanced computational models and solid network architectures, concerning the emerging digital connectivity, smart transportation, and sustainable energy solutions in ISC2. Hence, a systematic, multiscale modeling and experimentation framework, coupled with a secure, scalable and solid network synthesis framework is proposed. Two novel elements are part of the proposed research: development of a comprehensive urban cyber-physical network modeling and validation framework, initiatives in optimizing, synthesizing and validating solid network architectures using mixed-integer linear programming. Simulation cases concerning ISC2 are discussed, with nine objectives outlined. These objectives stress the importance of developing a comprehensive understanding of ISC2 in order to propose solid, cost-effective suggestions.

7.1. Future Trends

As the world is marching towards future technologies, Smart wireless communication has gained its prominent role as a critical kernel to enable and foster several emerging smart infrastructures, such as Smart City, Smart Grid, Smart Health, and Smart Transportation. However, the requirements of these smart infrastructures towards wireless connectivity can hardly be met with today's wireless networks. Smart Infrastructure cannot exist without smart wireless communication. As cities are becoming "intelligent," more people and machines have access to the infrastructure, which will inherently demand wireless and mobile radio connections. For instance, Smart City applications range from smart street lights, waste drums, water leakage detection, air quality monitoring, and transportation to smart parking. A common trait of the majority of these Smart City applications is the existence of a large number of sensors and actuators. However, wired connectivity is too costly and not feasible for broad scalability, while wireless connectivity also offers greater flexibility and ease of deployment. The reduction of cabling cost was quantified in a real case scenario of smart lighting. The results show the reduced capital expenditure of sensor deployment when wireless connections are employed. On the other hand, an abundance of eNB signaling, derived from the disablement of the "connect to internet" setting of mobile devices in direct-communication scenarios, is shown to significantly improve the performance when location-oblivious mobility prediction is employed. The proliferation of smart mobile devices and APs has urged the need for ubiquitous coverage in indoor environments and in outdoor wireless wideband networks. For the latter case, in order to meet the demand of exponentially increasing data consumption, 5G will provide extremely high data rate per unit area through the dense deployment of small cells. SIN will be further exploited to analyze and design beyond 5G wireless systems in an era of a massive fleet of cars equipped with wireless interfaces. Moreover, it is envisioned as a game changer of Smart Cities, as developing wireless technologies are shaping future opportunities in this domain. It is foreseen that transportation systems will represent the largest application of IoT (Internet Of Things) in cities. The potential benefits of IoT in transportation include vehicle-to-vehicle (V2V) communications for collision avoidance and improving traffic flow limit, as well as vehicle-to-everything (V2X) communications to enable infotainment, urban-sensing, and intelligent traffic-light signaling. These requirements are critical especially for the forthcoming vehicles, such as autonomous and connected vehicles, which will behave as a large number of mobile radio transceivers that will maximize the safety and efficiency of the traffic flow. This immense amount of data represents a huge opportunity for city management and will lead to better economic value, safety, efficiency, security, and sustainability as well as to some kind of new citizen services. On the other hand, the number of radio connections will experience staggering growth, thereby requiring research not only in ultra-reliable low-latency communications (URLLC) technologies, but also in scalable and smart network orchestration and management. As society infuses daily activities with broadband and 5G, new technologies, and use of the network will deeply shape the landscapes. The Internet and the ability to easily connect a global landscape is now a component so fundamental that often gets overlooked. It allows for an intersection of business and existence to be created, aiding in connections, communication, and an understanding of one another. It is the 'digital electric wave' revolution that drove all these aspects. The next thrust will once again rely on the network fabric to solve a grand challenge in massively distributed situational awareness. One important aspect is the wireless network and the upcoming fifth generation (5G). By 2022, the global mobile data consumption will reach 930 exabytes per year, three times the traffic observed in 2017. To tackle this, a fundamental transformation is necessary. In the next decade, the fifth generation of wireless network 5G will provide native support for a new kind of network infrastructure deployment, such as ultra-dense networks, multiple Radio Access Technology co-existence, and direct Device to Device communications. With an acceleration in the global rollout of 5G, research and deliberation have been conducted to better understand the multifaceted 5G digital challenge, and to make sure that the world is ready for the upcoming 5G services. This shares the contemplation about these examinations and implores other standards. Additionally, several other trends and potentiality in the future digital society are explored. In particular, an analysis has been made on how recent advancements of wireless communications, such as system-level simulation, mm-wave, and moving target detection, can stimulate and shape future research that might be undertaken to try to improve the versatility, robustness, and resilience of the network. And the hope is that this analysis will be of interest to many, often in a different place, looking at similar problems and possibly applying some of the same fundamental techniques to similar rigorous scientific traditions.

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