INSIST

Deliverable

D1.1.1 - State of the Art

Editor:

Özgür Devrim Orman

ITEA 3 Project 13021

February, 12th 2018

Document properties

Security	Confidential
Version	Version 2.0
Editor	Özgür Devrim Orman, Bor
Authors/ Contributors v2.0	Emine Ferraro, Argedor İsmail Hakkı Toroslu, Argedor Mustafa Eren, Verisun Şaziye Ersoy,Verisun Ulvi Ağca, Verisun Bilge Özdemir, Bor
Authors/ Contributors v1.0	Özer Aydemir, Bor Damla Tiryakioğlu, Bor Hülya Yurtman, Bor Gülsüm Çiğdem Çavdaroğlu, Koç Sistem Çağrı Kaçmaz, Koç Sistem Güven Fidan, Argedor Mustafa Eren, Verisun Sari Jarvinen, VTT Johannes Peltola, VTT Simo Pulkinnen, Valve

Abstract

This document includes the detailed snapshot of the current trends on the technologies relevant to Smart Cities. The research in this study is mainly based on three dimensions which are thought to be best indicators in determining tendencies; granted projects, patents and reports on commercial applications.

Table of Contents

1.Introduction

According to the World Bank records 53 % of the world's population now lives in towns, cities, and UNFPA (United Nations Population Fund) states that by 2030 this urban population is expected to reach slightly above 5 billion. Considering this growth trend, digitalization is not only a need but also a necessity for the sustainable wealth on earth and Smart Cities might just be the dawn of a new era; smart urban transformation. The long journey of Smart Cities can be dated back to the late 1960s, Mark Vallianatos explains very roots of the Smart Cities movement in Los Angeles as; *"Beginning in the late 1960s and through most of the 1970s, the little-known Community Analysis Bureau used computer databases, cluster analysis, infrared aerial photography to gather data, produce reports on neighborhood demographics, housing quality, help direct resources to ward off blight and tackle poverty. [1.1]"*

Smart City term can be basically defined as follows; *"A smart city is an urban development vision to integrate multiple information and communication technology (ICT) solutions in a secure fashion to manage a city's assets the city's assets include, but not limited to, local departments information systems, schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement and other community services. [1.2]"*

Also a more detailed definition can be given as; *"In literature the term smart city is used to specify a city's ability to respond as promptly as possible to the needs of citizens. Literature review highlights that various aspects referring to improve life in a city are mentioned in connection to the terms of smart city like: transportation, education, public administration, health care, security, green, efficient and sustainable, energy etc. In literature is shown that the most important area for start to transform a city in a smart one is the transportation system. This area has in view to use the modern transport technologies. Smart transportation systems are the best example of the harmony between development of city and modern technologies. [1.3]"*

The goal of building a smart city is; *"to improve quality of life by using technology to improve the efficiency of services and meet residents' needs. [1.4]"*

Whereas, the role of ICT in Smart Cities can be summarized as; *"ICT allows city officials to interact directly with the community, the city infrastructure and to monitor what is happening in the city, how the city is evolving and how to enable a better quality of life. Through the use of sensors integrated with real-time monitoring systems, data are collected from citizens, devices then processed and analyzed. The information and knowledge gathered are keys to tackling inefficiency. [1.5]"*

In Smart Cities literature, remarkable sources available for an intro;

The book of Smart City "How to Create Public and Economic Value with High Technology in Urban Space" by Renata Paola Dameri and Camille Rosenthal-Sabroux brings a clear vision while answering to these three important questions; How to define a smart city? How to design a smart strategy? and How to measure if smart actions really are able to create public value for citizens and a better quality of life in urban spaces?.

The following chapters of "Planning Support Systems and Smart Cities", Stan Geertman, Joseph Ferreira, Jr., Robert Goodspeed, John Still well editors, should also be addressed;

- In "Who's Smart? Whose the City? The Sociopolitics of Urban Intelligence" chapter Kian Goh presents two important findings: "*First, there is no one "smart* *city," even within a city. Second, differences in scales and ideologies of urban governance across cities have significant impact on the way that actors frame their priorities and objectives around the role of urban technologies.* "Finally, he speculates on *„the ways that urban networked systems might enable and empower a transformative planning. [1.6]"*

- In "Sentient PSS for Smart Cities" chapter Brian Deal, Varkki Pallathucheril, Yong Wook Kim and Haozhi Pan have discussed if the development of a useful planning support system (PSS) for a smart city requires that the PSS possesses a degree of sentience—an awareness of application context and user needs—that few if any current PSSs currently possess. [1.7]
- Additionally, in "MassDOT Real Time Traffic Management System" chapter Russell Bond and Ammar Kanaan are pursuing an innovative business model that provides real time travel time information to the public using dedicated highway signs covering over 700 miles of state highway and encompassing the entire metropolitan Boston area. [1.8]

In order to make a fine but quick decision on the trends, three sources should be taken into account; granted projects, patents and market. The first one, granted projects are remarkable sources for the technological developments and applications in the Smart Cities concept, some of these granted projects are briefly presented with their official definitions below;

Table 1: Projects

Project Name (Granting Program)	Information
TILAS (CelticPlus)	Aims to exploit the initial outcomes of different Smart City related projects with an associated large-scale IoT test-bed deployment. [1.9]
CitiSim (ITEA3)	Smart City 3D simulation and monitoring platform, main goal is devoted to the design and implementation of a new generation platform for the smart city ecosystem. [1.10]
MOS2S (ITEA3)	Novel and ubiquitous consumer-priced audiovisual sensors and data in particular, represent an important aspect of the Smart City environment, enabling a variety of applications for citizen information, participation, entertainment, experience, safety and security. [1.11]
ARTS (FP7)	Is committed to understanding the role and impact of transition initiatives in cities and examining the conditions that can aid accelerating change towards a sustainable low-carbon society. [1.12]
EU GUGLE (FP7)	Project aims to foster the EU-wide dissemination of the most efficient models and strategies for helping cities

	and communities to achieve a 40% greenhouse gas emissions reduction by 2020. [1.13]
PLEEC (FP7)	Project uses an integrative approach to achieve the sustainable, energy–efficient, smart city. By coordinating strategies and combining best practices, PLEEC will develop a general model for energy efficiency and sustainable city planning.[1.14]
READY4SmartCities (FP7)	Operates in a European context where other initiatives are currently running in order to create a common approach on Smart Cities. Such initiatives, even if of fundamental importance for the EU, have some relevant gaps not allowing them to fully cover fundamental aspects for Smart Cities, i.e. to define a common data framework allowing full interoperability among different city system, as well as a consistent vision on how ICT can support energy systems in smart cities. [1.15]
EPIC (FP7)	Is aimed to be the first choice service innovation and delivery platform (with Roadmap) for medium sized (50.000–500.000 habitants) cities across Europe, where any city can cost-effectively share, access and adapt a range of services to work smarter to meet the needs of most, if not all, their citizens, visitors and a wide range of business/social relations. EPIC will combine a first-of-its kind, industrial strength service delivery platform with discrete partner city application suites in order to create an end-to-end innovation ecosystem.[1.16]
LiveCity (FP7)	Aims to empower city inhabitants to interact with each other in a more productive, efficient and socially useful way, by using high quality Video-to-Video (v2v) over the Internet. LiveCity will pilot live high quality video-to-video applications in order to evaluate social utility and demonstrate value to the city citizens.[1.17]

PEOPLE (FP7)	Is focused on implementing innovative internet-web services to facilitate citizens' daily lives, using them as a primary source in the definition of requirements. PEOPLE aims at speeding up the uptake of smart cities through the rapid implementation, deployment and uptake of innovative internet-based services in order to allow facing the main challenges of developed cities at present and towards their future quality of life. This is enabled by designing and implementing user driven open innovation methodologies and processes.[1.18]
IS-COT (EUREKA)	To develop intelligent Urban Traffic Management System, using mathematical algorithms to predict and optimize traffic flow in urban area – cities. Comprehensive, intelligent Urban Traffic Management system is expected to enable control and optimization of traffic.[1.19]
NWVSS (EUREKA)	To create a video surveillance system designed specifically for mobile applications such as police, defense and outdoor security. The system allows video and audio collected from a moving vehicle to be recorded, transmitted and viewed by stationary or handheld clients.[1.20]
SAFEROADS (Eurostars)	The goal is to develop and test a new integrated system for traffic management. This application is focused on the control of real time traffic, collection of statistics about traffic flow, and development of a security system in order to detect high-risk situations and traffic violations.[1.21]
FacTuM (Eurostars)	Will develop a portable traffic management system for use at road works. Coordinated traffic data sensors will control display units (traffic lights, displays) in real-time and allow for the first time a broad, multimodal, traffic-dependent regulation of these sensitive traffic areas.[1.22]

SIREN (Eurostars)	Aims to develop a personalized tourism recommendation service which can be easily deployed and customized for cities around the world using harvesting, aggregation and categorization algorithms.[1.23]
SECAIR (Eurostars)	Aims to respond to very important security and safety issues in airport environments: providing a solution to monitor aircrafts, vehicles and staff moving around the movement area (runways, taxiways and aprons) in any weather condition, automatically and with high reliability.[1.24]
ASUA (CelticPlus)	Advanced Sensing for Urban Automation, Solutions for managing constrained devices in challenging environments, while enabling them to get connected by becoming parts of an advanced sensing system. The addition of new sensors to existing systems will be facilitated by designing flexible interfaces for enhanced interoperability.[1.25]
MONET (EUREKA)	Research and development of central database application and service for data evaluation, alerting and controlling of movements of transport objects and vehicles based on data exchange and requirements from different users' applications, with links to current telematics monitoring solutions.
Octopus (EUREKA)	An advanced site security and threat detection system, provides threat's live video/audio based tracking including continuous global positioning and the event-scene video/audio recorded information for debriefing. Consists of Sensor Modules, site Network and site Monitoring Unit.[1.27]
IS-COT (EUREKA)	Aims to develop intelligent Urban Traffic Management System, using mathematical algorithms to predict and optimize traffic flow in urban area – cities. Comprehensive, intelligent Urban Traffic Management system is expected to enable control and optimization of traffic.[1.28]

BORDIDEN (Eurostars)	New system for a complete, automatic, real-time identification of ground vehicles, This project is focused on the development of an automatic, combined system for the complete identification of vehicles. This device has three different modules, including both hardware and software levels: 1.-Number Plate Recognition; 2.-Colour Recognition; 3.-Magnetic Recognition.[1.29]
EICS (EUREKA)	Proposes to create a unified system that will allow automated Management of Disasters and other Emergencies. Uniquely, it will allow automated communications activity and decision making based on user-defined SOPs (Standard operating procedures).[1.30]
X-NETAD (EUREKA)	Project leverages on the spontaneous formation of Wi-Fi local Vehicular Ad-hoc NETworks, with direct connections between neighboring vehicles, in order to disseminate, very quickly and inexpensively, traffic alerts received from the UMTS network.[1.31]
i-SCOPE (CIP / ICT PSP)	Project plans to develop and test technologies for the so-called smart cities services based on interoperable 3D Urban Information Models.[1.32]
CITYKeys (Horizon2020)	Aims to develop and validate, with the aid of cities, key performance indicators and data collection procedures for the common and transparent monitoring as well as the comparability of smart city solutions across European cities.[1.33]
BRISEIDE (CIP / ICT PSP)	Aims at delivering: time-aware extension of data models developed in the context of previous/ongoing EU INSPIRE related projects (e.g. in the context of GMES, eContentPlus), application (e.g. Civil Protection) based on the integration of existing, user operational information and value added services for spatio-temporal data management,

	authoring, processing, analysis and interactive visualization.[1.34]
BrusSense	Proposes a particular approach, by developing a so-called community memory for urban environmental measurement surveys, focusing on noise, microclimate and atmospheric pollution. Goal is two folds; first to gather data in a quantitative way, using participatory mobile sensing, and second in a qualitative way, by social tagging.[1.35]
i-TOUR (CORDIS)	i-Tour will develop an open framework to be used by different providers, authorities and citizens to provide intelligent multi-modal mobility services. i-Tour client will support and suggest, in a user-friendly way, the use of different forms of transport (bus, car, railroad, tram, etc.) taking into account user preferences as well as real-time information on road conditions, weather, public transport network condition.[1.36]
RADICAL (CIP / ICT PSP)	Will enable the development and deployment of interoperable pervasive multi-sensory and socially-aware services, by leveraging Internet of Things, Social Networks and Living Labs; emerging from leading edge R&D results from the SmartSantander, BonFIRE, SocIoS, and +Spaces projects.[1.37]

Relevant patents also studied in this work and briefly summarized below;

Table 2: Patents

Patent ID	Information
US20140278029	Illustrates the self-organizing smart traffic control system. Methods and software for managing vehicle priority proximate to a potential travel-priority conflict zone, such as a roadway intersection, where travel conflicts, such as crossing traffic, can arise. Instructions based on the dynamic traffic control plan are communicated to devices aboard vehicles in the ad-hoc network, which display one or more virtual traffic signals to the operators of the vehicles and/or

	control the vehicles in accordance with the dynamic traffic control plan, which may account for a priority level associated with one or more of the vehicles. [1.38]
US20110261202	Illustrates the clustered intelligent monitoring system which use video analytics, event driven systems and policy management for the implement of the city wide safety.[1.39]
KR20160034754 (A)	The outdoor advertising products and how to manage outdoor signage census using smartphone. The invention relates to a total investigation of an outdoor sign using a smartphone and a method for managing an outdoor advertisement. [1.40]
US 9221385 B2	Emergency digital sign network with video camera, methods of operation, and storage medium. The disclosed subject matter provides a digital sign with a video camera. The digital sign and video camera are connected via a communications medium to a central computer. The central computer provides a way of changing the images displayed on the digital sign and of disseminating the video from the video camera either through real time forwarding/viewing or recording the real time video stream and playing back the recorded video to a user.[1.41]
CN102145157 (A)	Outdoor advertisement transfer membrane technology.[1.42]
KR20160006505 (A)	Outdoor advertising panel structure. The outdoor advertisement panel structure enables an LED and a light guide plate to be simply, quickly, and firmly assembled and installed, thereby having a superior assembly characteristic and maximizing a heat radiation capability. [1.43]
JP2016024386 (A)	Advertisement distribution system.[1.44]
CN205016198 (U)	A novel outdoor billboard. The billboard, is including fixing at subaerial advertisement support and fixing advertisement frame and the cleaning

	device at advertisement support top, and cleaning device includes.[1.45]
KR20150139215 (A)	Display Apparatus for Outdoor Advertisement with Heating Function. The invention operated to stably provide an image according to an environment of a surrounding area.[1.46]
US 8483940 B2	Determining road traffic conditions using multiple data samples.[1.47]
US 20110095908 A1	Mobile sensing for road safety, traffic management and road maintenance.[1.48]
US 6633238 B2	A system and method for controlling traffic and traffic lights and selectively distributing warning messages to motorists includes a controller to determine appropriate action based on traffic congestion parameters. [1.49]

Market analyses also provide good indicators for estimating the trends; for instance according to "Outdoor Advertising – A Global Strategic Business Report, Global Industry Analysts, Inc. "; Outdoor Advertising market driven by the growing acceptance of digital platforms for out-of-home advertising, is expected to reach $50.7 billion by 2020. Currently by the market, traditional static billboards and posters are replaced globally with digital signage applications. Digital billboards are expected to dominate the market, in the near future with new developments in technology, launch of innovative displays, and their ability to attract audience attention. However, in the report the following are summary of trends and drivers; "*Growing Replacement of Traditional Static Billboards with Digital Signage Spurs Growth", "Innovations in 3D & Multi-Faceted Prismatic Billboards Bring in New Opportunities", "Wireless Digital Signage Solutions Grow in Popularity", "Expanding Applications in the Financial Services Industry Fuels Market Growth", "Increasing Adoption of Online Advertising: A Major Challenge", "Unfavorable Regulations Hamper Market Growth. " [1.50]*

Furthermore, global driving forces of the market defined as; *„rising urbanization, digital outdoor advertising and global economic development. "*In another report [1.51]. However, in the same report, low-cost advertising medium, improved audience measurement and commuting trends are indicated as additional factors. On the other hand, according to the report application of various regulatory norms and standards enforced by governments worldwide limits the market. In safety and governmental restrictions concern, report says that „stringent government restriction on LCD advertising screens pertaining to limiting light/color intensity to ensure drivers safety or reduce annoyance for residential homes at night is restricting market growth.". Thinking the opportunities, report says that; *„The major opportunity for the market lies in large area display technologies which can be an effective substitute for the existing screen printed electroluminescent (EL) displays. Some of the major players in the global billboard and outdoor advertising market include Capitol Outdoor, LLC, Outdoor*

Advertising Association of America, Inc., Formetco Incorporated, Daktronics Dr., and Watchfire Signs., among others."[1.51]

1.1. Insist Overview

The INSIST project is a smart connected ecosystem that aims for the integration of proprietary and public cameras, sensors, and advertisement infrastructures to offer value added services that increase the comfort and safety of public spaces in the following areas:

1.1.1 Traffic Management

Through the use of social media channels, and public thematic maps INSIST will offer numerous traffic management services for public spaces, including route optimization and visualization, and travel estimation. This will be achieved using implementing semantic parsing approaches to public social media comments about current city traffic, using GPS based vehicle tracking information, and processing thematic traffic maps by image processing techniques. All data about the traffic will be collected and will be processed in order to calculate optimal and fastest routes, and inform citizens about current traffic accidents.

Intelligent Transportation Systems (ITS) are advanced applications which, without embodying intelligence as such, aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks [1.52]. ITS means to apply information and communication technologies (ICT) to the transport sector [1.53].

The Ministry of Land, Infrastructure, Transport and Tourism of Japan defines an ITS as a new transport system constructed with a goal of alleviating road traffic problems such as accidents and congestion using state-of-the-art information and communication technologies to create an information network based on people, automobiles, and roads [1.54].

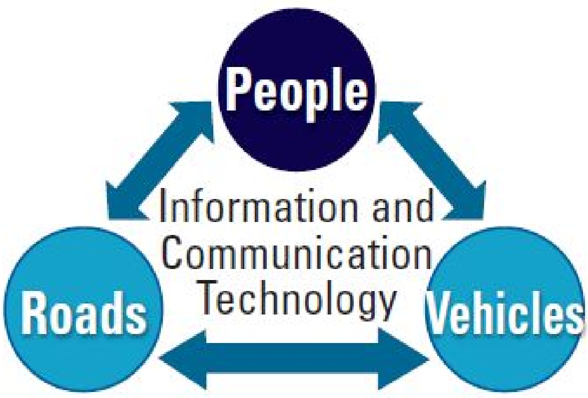

Figure 1 : ITS [1.54]

In 2010 EU Directive defines ITS as systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport [1.55].

ITS can be analysed in three different stages.

- The period from 1996 until mid-2004 came to be known as the first stage of ITS;
- The period from 2004 until 2013 is second stage of ITS;
- The period from 2013 until now is next generation of ITS.

The first stage of promotion was the practical use of the technology, the second stage was the dissemination and accelerated spread of the technology through society, and since 2010, the realization of a sustainable mobile environment has been promoted as the next generation of ITS's response to social issues [1.56].

Intelligent transport systems aim to improve the traffic flow in a secure and efficient manner by collecting and communicating traffic-related data [1.57].

Enhanced and secure traffic management allows making the best use of the existing infrastructure and the processing of traffic events in an efficient, eco-friendly and secure manner [1.57]. ITS can create clear benefits in terms of transport efficiency, sustainability, safety and security [1.53]. ITS is based on the principle that cooperative parties such as ITS stations in vehicles or road side units) exchange information among each other in terms of standardised message sets. An ITS station receives the data from environmental components and analyses the incoming data. For a smart city system, in its first phase, applications related to traffic lights are of primary interest. The technology enables the transparent prioritisation of public transport vehicles and of emergency vehicles at intersections. Collection traffic data provides a detailed picture of the traffic situation and improves traffic control and management [1.58]. ITS are not limited to automobiles, but also include railways, aircraft, and shipping traffic [1.56].

The European Commission's ITS Action Plan aims to accelerate and coordinate the deployment of ITS in road transport, including interfaces with other transport modes. ITS Action Plan comprises 24 specific actions which can be grouped into six priority action areas [1.59]:

- Action area 1: Optimal use of road, traffic, and travel data
- Action area 2: Continuity of traffic and freight management ITS services on European transport corridors and in conurbations
- Action area 3: Road safety and security
- Action area 4: Integration of the vehicle into transport infrastructure
- Action area 5: Data security and protection, and liability issues
- Action area 6: European ITS cooperation and coordination

Real-time traffic and travel information aims [1.59]:

- make private, especially safety-related, traffic information available to public authorities,
- ensure fair and transparent access to public traffic and travel-related data
- promote public-private cooperation to improve traffic and travel information
- increase data quality and improve multimodal cooperation

Data sources of the intelligent transport systems such as vehicles, disturbances in the network, weather are needed to communicate with each other (V2V) and to the traffic control center (V2I) [1.57]. This communication is required so that traffic users can be informed, congestions reduced, critical situations avoided, transportation process can be planned efficiently and the traffic controlled in a selective and dynamic manner [1.57].

An ITS system supports [1.57]:

- to increase traffic safety
- to improve traffic flow efficiency
- to protect the environment
- to collect and manage informations

1.1.2 Advertising and Atmosphere

INSIST aims to provide smart advertising and information services for public spaces, such as adaptive commercials that change according to the atmospheric and weather conditions, and other environmental variables. As an instance, INSIST can help display crucial information and announcements in the case of accidents or emergencies. Those services will be achieved by activity recognition and social media engineering.

2. Current Trends

2.1. Base Technologies

2.1.1 IT Issues

There are numerous aspects such as natural environment, socio-economic pressures, demographic factors and increasing urbanization which has direct impacts on public transport to varying degrees. Technology, climate change, the need for organization and the desire for individual transportation are drivers of change across the sector.

Advanced computer technology has undergone an almost incomprehensible transformation. Although the goals and objectives of the transportation community is almost the same but the challenges of rapidly developing technology are greater than ever. For example, data management capabilities have greatly improved the management of resources. However, accompanying the positive effects are the challenges of implementing, supporting and financing these technologies in the transportation domain.

Narrowing the gap between cutting-edge technology and its applications, as well as identifying the missing links for applying technology in transportation will be the ongoing challenge.
The paper issued by Jeffrey L. WESTERN and Bin RAN asses very well (in the text entitled as “Information Technology in Transportation, Key Issues and a Look Forward” [2.1]) these technological challenges and relevant solutions in such areas as in following aspects:

- Applying information systems and technology in the transportation field;
- Applying system-user interfaces (e.g., interactive graphics) as well as data management and data sharing;
- Using web technologies (Internet, intranets, and extranets) in transportation;
- Prioritizing research, development, and demonstration programs to augment work presently underway;

- Encouraging the use of common information system and information technology semantics and standards in the transportation field;
- Facilitating and monitoring technology transfer as a “user advocate” among transportation organizations, vendors, and universities; and
- Evaluating the impact of computer technologies on transportation organizations, including gains in productivity.

The growing concerns about the application of advanced computer technology in transportation involve the following issues:

- IT,
- Management,
- Data sharing and interoperability,
- Transportation applications, and
- Information dissemination

2.1.1.2 IT Issues

IT issues in transportation domain can be examined under several sub-topics. As referring to paper issued by Jeffrey L. WESTERN and Bin RAN in the text entitled as “Information Technology in Transportation, Key Issues and a Look Forward” [2.1], we can pursue the topics which are listed in this paper:

2.1.1.2.1 Transportation Applications of Web Technologies

In applying web technologies, the focus in the new millennium will be on advances in realtime technologies, such as “zero-latency” and push technologies.

2.1.1.2.2 Internet, Intranet, and Extranet Information Technologies

Computer networks offer everything from new forms of communication. Beside the most famous computer network, the Internet, there exist also other kinds of computer networks including smaller networks called intranets and extranets.

The transportation community should emphasize the applications of the Internet, intranets, and extranets in the design, construction, and operation of transportation facilities, specifically in the following areas:

- Data exchange and communication over the Internet or extranets;
- Cross-platform integration of transportation information sources;
- Dynamic generation and presentation of transportation information on the Internet;
- Information dissemination and management using organizations’ intranets; and
- Integration of transportation databases with the Internet, intranets, and extranets.

2.1.1.2.3 Anticipating Future Revolutions in IT

The transportation community should identify and prepare for future revolutions in IT that will have an impact on transportation. Technological progress and the advancement on several notions such as AI and automation, will have a major impact on transportation community where self-driving cars and interconnected vehicles will redefine the nature of work in the coming decade.

2.1.1.2.4 Mobile Computing

The market penetration of hand-held and in-vehicle computers will provide a platform for many transportation applications. How can we take advantage of these new technologies?

2.1.1.2.5 Virtual Reality

Virtual reality is versatile field of technology and this concept should be considered for facility design and should be investigated in depth.

2.1.1.2.6 High-Bandwidth Wireless Networks

One of the main question in technology is the efficiency. How can high-bandwidth wireless networks rise the efficiency in transportation technology in order to deliver a robust service to end users?

2.1.1.2.7 Consumer Electronics Explosion

The consumer electronics (CE) market is poised for explosive growth. Market-ready products supporting mobile computing and electronic commerce, and wireless communications supporting E911 locations, smart cards, and the like have made their debuts already. What impact will they have on public and private transportation services? Which CE technologies offer major opportunities for reengineering? For example, how can motor vehicles exploit e-commerce? We barely understand the dynamics of the boundary between the public and private sectors and are about to be overcome by technologically savvy consumers.

2.1.1.2.8 New Philosophies and Techniques for Systems Development

How the technical foundations will guide the development of new systems? What is the concept of artificial in “systems?” How should the ideas of nonlinearity, complexity, and cybernetics be introduced into transportation systems? Institutions of higher education should address those questions to explore these areas. The gathering of transportation data (for vehicles, rail, and aircraft traffic), analytic processing, and information presentation to transportation operation centers is vital in the 21st century.

Other topics and types of IT that will be of increasing interest to the transportation community include ·

- Software and hardware security, ·
- Mobile communications,

- Automatic equipment identification,
- Electronic data interchange,
- Global positioning systems,
- Geographic information systems (GIS),
- Visualization and animation,
- Electronic funds transfer,
- Voice recognition,
- Sophisticated bar-coding,
- Airborne ground surveillance,
- Satellite ground surveillance and tracking,
- Very large-scale computing,
- Distributive and client-server technologies, and
- Advanced analysis and modeling computing.

2.1.1.2 Management Issues

2.1.1.2.1 Standardized Methods for Benefit–Cost Analysis

Benefit-Cost (BC) analysis has been used to evaluate transportation projects, and standardized methods have been developed in recent decades. The experience gained in this domain shows us it is important to develop standardized methods for benefit and cost analysis for the implementation of IT in transportation projects. BC analysis traditionally has been difficult for IT. Managers and politicians are less patient and less willing to accept the benefits of IT.

2.1.1.2.2 Software Safety

The safety of transportation systems are depending on the software you use. This has led to increasing quality and reliability requirements for implemented software. As software becomes a more integral part of transportation systems, software safety issues arise. We must ensure that the software does no harm if it should fail. Safety and security are not the same but interrelated. Safety goes beyond security. Software can fail because of a bug, hardware failure, or another problem. It is important to ensure that if the system software does fail, there is no resulting injury or loss of life.

2.1.1.2.3 Software Systems

With the good old days of “roll-your-own” software systems gone forever, how does an agency obtain new systems and components? How do you design and build systems from components? What new skills and roles does your information system (IS) staff need? How do you acquire, benchmark, deploy, operate, upgrade, and retire systems in this new environment? The last generation of systems managers witnessed the hardware “appliance.” What is the software equivalent?

2.1.1.2.4 Standards and Guidelines

What are the specific standards and guidelines that IS leaders in the transportation world can rely on for practical application in a dramatically changing environment? The transportation community should support standards development—such as Standards on Software, Carnegie–Mellon's Software Engineering Institute Capability Maturity Model, ISO9000-3, the Project Management Institute's Guide to the Project Management Body of Knowledge, and other documents providing standards and guidelines.

2.1.1.2.5 Technical Concerns

What are the risks associated with enterprise resource planning implementations?

2.1.1.3 Data Sharing and Interoperability

2.1.1.3.1 Management of Transportation Data

There are multiple dimensions in transportation data where it is derived across various systems, data resources and devices as well. Management of transportation data from an IT point of view, or data storage and data delivery is the challenge and has to be considered.

2.1.1.3.2 Exchange and Sharing of Transportation Data Sets

Ideas and experiences in field of technology can lead us to develop more apt systems. In order to develop best transportation facilities, it is highly important to exchange ideas and experiences either through conference presentations or journal publications. These good ideas and experiences come mostly from analyzing or studying real-world data. At present, even if authors who publish their work would like to share their data, there is no well-established place to organize and disseminate them. Furthermore, data are expensive to collect. If we know that relevant data are available, we do not have to collect them again, or we only need to supplement the data that already exist. This would save both money and time. So, as it is argued in the text entitled as "Information Technology in Transportation, Key Issues and a Look Forward" by Bin Ran and Jeffrey L. Western [2.1], the transportation community can encourage the following activities related to exchanging and sharing transportation data sets:

- Determine what types of data are useful in terms of planning, design, operation, safety, and maintenance of transportation facilities. Determine how to classify the data.
- Determine the format and standard for publishing data sets. For instance, the data should be saved and published in standard formats. The data should then include a description of how they are collected, what and how to use them, where to get them, and so on. Since data are collected in the real world, we also might require each data set to specify at least one location reference suitable for GIS geocoding, making it possible find out what data a particular location has by clicking on a map.
- Define standards for disseminating the data.

2.1.1.3.3 Interoperability

Interoperability of the developed systems is the crucial goal for the transportation community.

2.1.1.4 Transportation Applications

2.1.1.4.1 Aging and Disabled Drivers

The transportation community needs to investigate how IT could provide assistance to the increasing population of elderly and disabled drivers.

2.1.1.4.2 Intelligent Vehicles

How IT will affect the deployment of intelligent vehicles and how telematics will change the operations of transportation agencies and the behavior of motorists needs to be evaluated.

2.1.1.4.3 Vehicle and Highway Automation

The main question in automation in the field of transport is "How to advance to full automation?"

2.1.1.4.4 Collision Warning and Avoidance Systems

The transportation community needs to evaluate how well collision warning and avoidance systems and crash mitigation systems could work, what percentage of the annual 40,000 accident deaths could be prevented by such systems, and whether such systems should be mandatory.

2.1.1.4.5 Information Dissemination

Public expectations on transportation industry, especially how the public interacts with government organizations, should be assessed more in detail. This is important as people become accustomed to the availability of timely information in their daily lives.

2.1.2 Data Science

In this technological age we're living, each second there is a huge data generation. In 2003, when internet became common, data generated as much as throughout the human history in just one year and this trend it continues. According to IDC the amount of data generated in 2020 will be 44 times the data in 2009[2.2].

The term "big data" is defined as "a data sets that are so large or complex that traditional data processing applications are inadequate". Challenges include analysis, capture, data curation, search, sharing, storage, transfer, visualization, querying and updating, and information privacy. The term often refers simply to the use of predictive analytics or certain other advanced data analytics methods that extract value from data, and seldom to a particular size of data set [2.3]. Accuracy in big data may lead to more confident decision making and better decisions can result in greater operational efficiency, cost reduction and reduced risk.

These led to the concept of "data science" which configures data at hand, generates data models and uses these models for product and service processes and decision mechanisms. Data science is generally defined as "an interdisciplinary field about processes and systems to extract knowledge or insights from data in various forms, either structured or unstructured, which is a continuation of some of the data analysis fields such as, programming, statistics, data mining, and predictive analytics [2.4]". Data science is a general concept including MIS at the most abstract level to the prediction algorithms at the lowest level.

Figure 2 : Data Science [2.5]

In today's world data is an important metric and business decisions are based upon it. Companies have a look at their and field's current and future situation and they set a course for whether to take an action or not on whether when they designate new investments or analysing their growth strategy. Companies began to invest more on data analytics and data analysis for to capture a competitive advantage and to provide a better service and product portfolio at productivity, profitability and sustainable production processes. Hence data usage and data analysis grew in importance. Data analysis is the analysis of large data containing different data sets. In terminology data analysis is defined as "a process for obtaining raw data and converting it into information useful for decision-making by users. Data is collected and analysed to answer questions, test hypotheses or disprove theories. [2.6]" Steps of the data analytics are: problem definition, design needs, data pre-processing, analytical processing on data, visualizing data. Advantages of using data analysis are more effective sales or service, new business or revenue opportunities, better quality and customer service; improve of operational efficiency, competitive to be used in a healthier environment and other areas of business.

Data analytics integrates statistics and modern computational method of calculations to create business value and it gives access to companies to access information and tools that they need to reach their potentials. In terminology data analytics is defined as "It is primarily conducted in business-to-consumer applications. Global organizations collect and analyze data associated with customers, business processes, market economics or practical experience. Data is categorized, stored and analysed to study purchasing

trends and patterns." [2.7] In an interview David Kasik, who is Boeing's Senior Technical Fellow, in visualization and interactive techniques replied to what is the difference between data analysis and data analytics question as "Data analytics is a broader term than data analysis and includes data analysis as necessary subcomponent. Analytics defines the science behind the analysis. The science means understanding the cognitive processes an analyst uses to understand problems and explore data in meaningful ways. Analytics also include data extract, transform, and load; specific tools, techniques, and methods; and how to successfully communicate results".
"Data science employs techniques and theories drawn from many fields within the broad areas of mathematics, statistics, operations research, information science, and computer science, including signal processing, probability models, machine learning, statistical learning, data mining, database, data engineering, pattern recognition and learning, visualization, predictive analytics, uncertainty modeling, data warehousing, data compression, computer programming, artificial intelligence, and high performance computing" [2.6].

Most researchers agree that the following fields are directly related to data science:

- Statistics
- Machine Learning
- Data Mining

The high-level process of data science is usually called as "data analysis". This term refers to analysing and making sense of the data. This can be done by using well-known statistical methods or machine learning techniques; or in general using tools and techniques of data mining.

Statistics is one of the oldest branches of mathematics dealing with the collection, analysis, interpretation, presentation, and organization of data. It has been used in data analysis for centuries. Nowadays, with the explosion of data, new and more advanced data analysis techniques are needed.

"Machine learning" is a branch of artificial intelligence. Machine learning is defined as the ability to learn models directly from data without programming it. It is one of the most remarkable technologies with many recent interesting and life changing applications. In fact, today we use these learning algorithms unwittingly in many areas. For example, search engines like Google uses learning algorithms. Facebook automatically recognizes your friends on your photos uploaded to Facebook through machine learning. Today, many companies use machine learning algorithms to process their web log data. For example, by detecting their users' behaviours, companies aim to provide better service to them. Spam filters, recommender systems, ad placement, credit scoring, fraud detection, stock trading, computer vision and drug design are some of the most well-known applications of machine learning techniques.

"Data Mining", on the other hand, can be defined as the computational process of knowledge discovering from large data sets. Specifically, data mining is the non-trivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns from huge volume of data. Indeed, machine learning and database are two main supporting technologies for data mining. Since data mining is about "big data", specialized tools and techniques are needed to handle this huge data and simply, database offers data management techniques. Moreover, machine learning provides tools and techniques for the data analysis.

For traditional machine learning research, massive data is not anticipated. Instead, usually the data is more complex. Therefore, many machine learning techniques are designed to handle small and medium-sized data which are not suitable for massive data. Therefore, recently researchers of the data mining focused on developing some specific and non-trivial transformations to these techniques for massive data. As an example, algorithms running in polynomial time may be considered very good for traditional small data sized machine learning applications. However, for data mining application on massive data cubic algorithm is not acceptable. To overcome this problem, efficient data structure and data scheduling strategies, which database is good at, may be used to transform the machine learning algorithms.

Furthermore, data mining introduced new techniques which did not existed in machine learning. The most well-known one is association rule mining. Association rule mining could be solved as correlation analysis in statistics if the data size is not large. The trouble in association rule mining is totally by the massive data size. For example, we cannot scan the whole database too many times, the computation ability and memory storage cannot afford too many intermediate results, etc.

Data mining is similar with machine learning with this objective. "Both systems search through data and they look for patterns. However, instead of extracting data for human comprehension -- as is the case in data mining applications -- machine learning uses that data to detect patterns in data and adjust program actions accordingly. Machine learning algorithms are often categorized as being supervised or unsupervised. Supervised algorithms can apply what has been learned in the past to new data. Unsupervised algorithms can draw inferences from datasets" [2.8].

To sum up, the main difference between machine learning and data mining lies in the size and complexity of the data. In data mining the data is huge and usually less complex than the data processed with typical machine learning methods. In addition, statistical methods are also used in data mining. So, data mining is an interdisciplinary subfield of science. It is the computational process of discovering patterns in large data sets involving methods at the intersection of artificial intelligence, machine learning, statistics, and database systems. Since in today's applications the data is very large we will be focusing on data mining, mostly using machine learning methods.

The data generated by the computer system is worthless alone; they do not have any meaning when viewed with bare eye. When these data are processed in accordance with a specific idea, then, it becomes meaningful. This conversion process that generates meaningful information from raw data can be made with data mining. "The overall goal of the data mining process is to extract information from a data set and transform it into an understandable structure for further use." [2.9]

Data mining is a process of the extraction of useful information from the data that was available but previously unknown. This can be done in several different ways. These include clustering, classification, data summarization, analysis of the change, detection of deviations etc. "The process of data mining typically consists of 3 steps, carried out in succession: data pre-processing, data analysis, and result interpretation." [2.5]

A data mining system has the following basic components:
1. Database, data warehouse and other storage techniques
2. Database or Data Warehouse Server
3. Knowledge Base
4. Data Mining Engine
5. Pattern Review
6. User Interface

One of the particular instances of a data mining techniques is recommender systems which typically require techniques and methodologies from other neighbouring areas such as Human Computer Interaction or Information Retrieval. In a world where the number of choices can be overwhelming, recommender systems help users find and evaluate items of interest. However, most of these systems bear in their core an algorithm that can be understood as a data mining technique.

Today Social Media has become one of the most important domains for data scientist. Social Media is a global forum for people to express their subjective thoughts, opinions, and feelings. Social media analytics is the practice of gathering data from blogs and social media websites and analysing that data to make business decisions. People express their opinions about almost anything like products, social events, and news through different Social Media services of which have the following common features:

- Social media are Web 2.0 Internet-based applications,
- User-generated content (UGC) such as text, digital photo or digital video posts are the lifeblood of the social media organism,
- Users create their own profiles for the website or app, which is designed and maintained by the social media organization,

- Social media facilitate the development of online social networks by connecting a user's profile with those of other individuals and/or groups.

Ona of the most important problems on social media data is sentiment analysis. Sentiment analysis aiming to determine the attitude (sense, emotion, opinion etc.) of a speaker or a writer with respect to a specified topic has become a major area of interest in the field of NLP and social media. Various statistical and linguistic methods have been developed for the Sentiment Analysis of English texts for different domains. In the case of Turkish and other morphologically rich languages, however, sentiment analysis is a new field of research and not much work has been published in this field.

Since the beginning of 2000, deep learning was a breakthrough in artificial intelligence, and began to spread. Deep learning algorithms, which are a new technology in artificial intelligence, had brought a different dimension in recognition machine image and sound. In terminology, deep learning is defined as "part of a broader family of machine learning methods based on learning representations of data" [2.10]. In MIT technology review they advert deep learning as "with massive amounts of computational power, machines can now recognize objects and translate speech in real time. AI is finally getting smart" [2.11].

2.1.3 Multimedia Streaming

T.V. Wilson [2.12] gives brief, humorous and very good explanation of the video streaming history;

> *"In the early days of streaming media -- the mid-to-late 1990s -- watching videos and listening to music online wasn't always fun. It was a little like driving in stop-and-go traffic during a heavy rain. If you had a slow computer or a dial-up Internet connection, you could spend more time staring at the word "buffering" on a status bar than watching videos or listening to songs. On top of that, everything was choppy, pixelated and hard to see. Streaming video and audio have come a long way since then."*

In 2008, Microsoft introduced Smooth Streaming, a compound approach to video delivery which offers both benefits of custom streaming protocols and leverages HTTP and existing network infrastructure. Smooth Streaming also supports adaptive bitrate (ABR) delivery, which provides faster startup and seek times, minimal buffering, and a smoother playback experience to viewers. HTTP-based streaming rapidly generated an impulse, and other major market actors were quick to invest in the technology. In 2009, Apple entered the market with the introduction of HTTP Live Streaming (HLS). In 2010, Adobe shifted its focus away from custom streaming protocols with the release of HTTP Dynamic Streaming (HDS). And since 2010, major streaming and media companies, including Microsoft, Google, Adobe, Netflix, Ericsson, and Samsung, have been collaborating on MPEG-DASH, an open standard for adaptive video streaming over HTTP.

According to Panopto [2.13] the following list is a brief answer of "What makes a video streaming protocol modern?" question;

> *"1. Chunked delivery: With modern streaming, video files are divided into short multi second segments that are sent across the wire. Depending on the protocol, the segments can range from 2-10 seconds in length. By contrast, custom streaming protocols treat videos as monolithic blobs of information.*
> *2. HTTP communication: Video segments are sent across the internet or corporate WAN using the standard HTTP protocol. Specifically, all Modern Streaming communications rely on TCP ports 80 (for unencrypted HTTP communication) and 443 (for SSL-encrypted communication).*
> *3. Stateless interaction: When a client is watching a video stream, each request for subsequent video segments is independent of previous requests. In other words, there's no persistent connection between client and origin server during video playback.*
> *4. Cache-friendly: Chunked delivery is what enables Modern Streaming to work in concert with HTTP caches that are ubiquitous on the internet, in content delivery networks (CDNs), and in many corporate networks. This has major benefits for network bandwidth management and WAN optimization—topics discussed in greater detail below.*
> *5. Adaptive-bitrate (ABR) playback: Videos delivered using modern protocols are encoded at multiple quality levels. During playback, the client's available bandwidth determines which quality level will provide the smoothest playback experience, and adjustments are made dynamically to minimize buffering while providing high quality playback.*
> *6. Passive network architecture: When video fragments are in transit on the network, intermediary nodes simply route the fragments toward their final destination, and in some cases, also cache the fragment. The intermediaries never execute any specialized code or modify the video fragments.*
> *7. Internet-intranet symmetry: By default, modern protocols like HLS, DASH, Smooth, and HDS treat corporate WANs works no differently than the public internet. Both are passive, stateless networks comprised of hardware and software that can route video chunks to their final destination and cache video segments as needed."*

In recent years, most large businesses have implemented web caching as part of their network infrastructure. For these organizations, Modern Streaming offers nothing but opportunity. HLS, DASH, and other HTTP streaming protocols were built explicitly to work with web caching infrastructure. Web caching systems improve the response times of websites, reduce the load on content origin servers, and improve resource availability by using cached content in cases where the origin server is unavailable. Popular web caching technologies include Nginx, Squid, Varnish, and WinGate, as well as the Apache and Microsoft IIS web servers.

Looking to the video streaming through the business communications and entertainment perspective, we clearly see that, streaming video has started to become a “new normal” in the enterprise world. The video is everywhere; it is embedded in both our personal and business lives, it is in everywhere we look, interact, search, and learn. Enabled by the remarkable developments in the relevant fields such as video compression, network connectivity, cloud storage, and bandwidth optimization, the adoption of video has never been greater. According to this results International Data Corporation (IDC) identifies two main categories of video [2.14]: video that supports the business and video is the business, and indicates that;

> *“This basically divides the market into enterprise video, comprising one-way and two-way streaming, and media and entertainment video which mainly consists of one-way video streaming/broadcasting.”*

According to IDC [2.14] “video is the business” case can be defined as follows;

> *"Video is the business" applies to one specific industry sector, in this case, media and entertainment. Video has no supportive function here nor is it seen as the business-critical application; video broadcasting simply is the business product. This type of video is streamed or broadcast from "one to many" and, like enterprise video (streaming), it has a massive reach and is therefore a very powerful medium. In this line of business or industry sector video streaming/broadcasting is done via various digital platforms such as IPTV, cable, satellite, and online (fixed and mobile) to deliver live TV and video on demand (VOD) as well as video advertising.”*

According to MarketsandMarkets 2017 report [2.15], video streaming concept and its market are defined as below;

> “The video streaming software market comprises software such as transcoding and processing, video management, video delivery and distribution, video analytics, and video security. The software is used to deliver videos over the internet, for corporate internet communication as well as for the live audience. Videos are a crucial element for corporate communications. They not only reduce the employee training costs, but also increase the efficiency of corporate communications. Video streaming works on the data streaming technique, where the video files are compressed and sent in a chunk to a requesting device. Streaming a video needs a compatible video player for connecting it to a remote server.”

In the same report video streaming evolution over the years is shown as in the Figure X below.

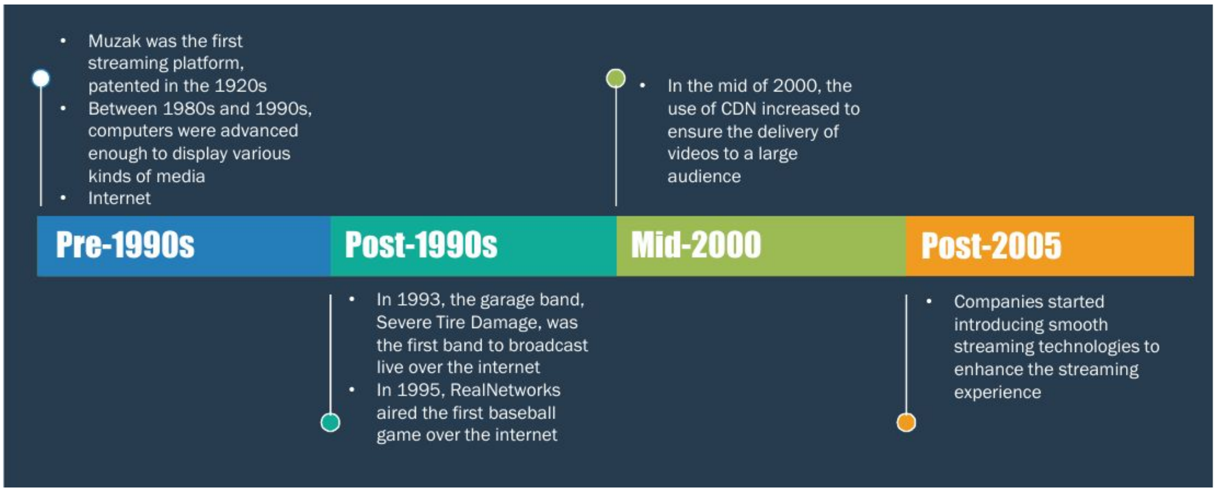

Figure 3 : Evolution of video streaming over the years.

In the same report Brightcove, Inc., Haivision, Inc., IBM Corporation, Kaltura, Inc., Ooyala, Inc., Panopto, Polycom, Inc., VBrick, and Wowza Media Systems, LLC are indicated as some of the top players in the video streaming software market, and 25 top players are determined by product offerings and business strategies and shown in Figure X below.

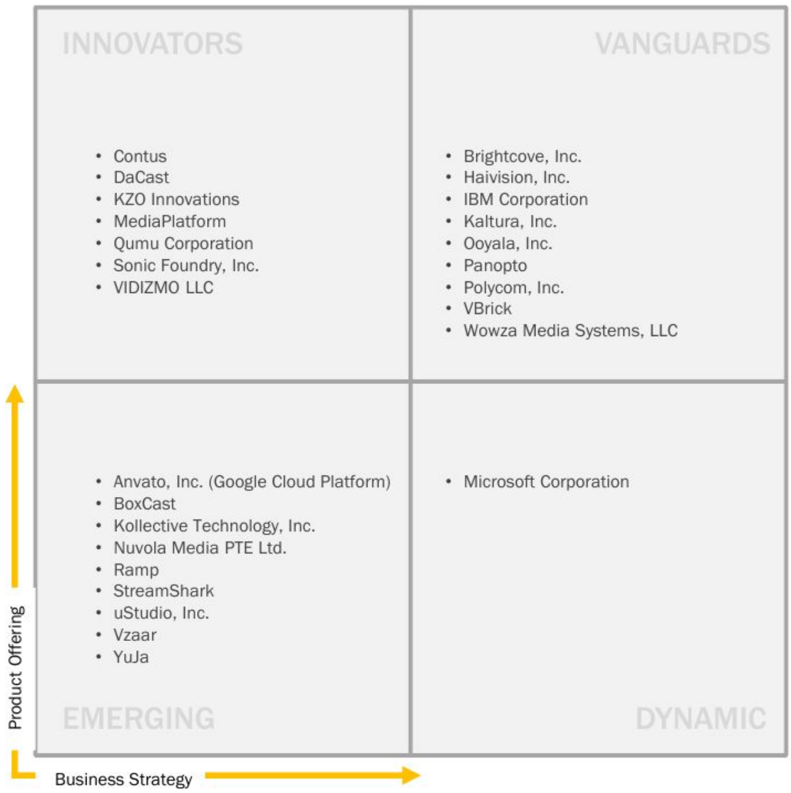

Figure 4 : Top 25 players in the market.

Vendor evaluations given in Figure 4 above are based on 2 broad categories: product offerings and business strategies. Each category carries various criteria based on which the vendors have been evaluated. The evaluation criteria considered under product offerings include the breadth of offering, feature, delivery mode, and product support. The evaluation criteria considered under business strategies include reaching (geographic presence), industry coverage, channel network, viability, roadmap, and inorganic growth.

According to the same report;

> *"VANGUARDS*
> *Vendors who fall into this category receive high scores for most of the evaluation criteria. They have strong and established product portfolios and a very strong market presence. They provide mature and reputable solutions. They also have strong business strategies. The vanguards in the video streaming software market are Brightcove, Inc., Haivision, Inc., IBM Corporation, Kaltura, Inc., Ooyala, Inc., Panopto, Polycom, Inc., VBrick, and Wowza Media Systems, LLC.*
> *INNOVATORS*
> *Innovators are the vendors who have demonstrated substantial product innovations as compared to their competitors. They have very focused product portfolios. However, they do not have very strong growth strategies for their overall business. Innovators in the video streaming software market are Contus, DaCast, KZO Innovations, MediaPlatform, Qumu Corporation, Sonic Foundry, Inc., and VIDIZMO LLC.*
> *DYNAMIC*
> *Dynamic vendors are the established vendors with very strong business strategies. However, they are low in the product portfolio. They focus on a specific type of technology related to the product. Microsoft Corporation is the dynamic vendor in the video streaming software market.*
> *EMERGING*
> *Emerging vendors are the vendors with niche product offerings. They are starting to gain their position in the market. They do not have very strong business strategies as compared to other established vendors. They might be new entrants in the market and require some more time before gaining significant market traction. Emerging vendors in the video streaming software market are Anvato, Inc., BoxCast, Kollective Technology, Inc., Nuvola Media PTE Ltd., Ramp, StreamShark, uStudio, Inc., Vzaar, and YuJa."*

According to the trends in 2017, bandwidth dedicated to video traffic is expected to make up 74% of internet use. Nowadays, most of the time, users are watching content on more than one screens at once. Often that means watching content on a phone while at the same time watching on a TV or computer screen.

OTT video stands for "Over The Top," which is a growing trend in content broadcasting. Essentially, OTT video refers to media companies providing their TV shows, films, and other video content via the internet "over the top" of traditional broadcasting channels. Live streaming OTT video content is excellent for events like concerts, sports, and similar happenings. Twitter's trial of live streaming NFL games was a significant achievement, reaching more than 20 million viewers. In fact, both live streaming and on-demand OTT video content are expected to become more mainstream in 2017.

Virtual Reality (VR), especially VR streaming, is becoming more widespread, and VR video is likely to be the future platform of choice. In the meantime, 360° video is a bridge technology that is coming into its own, for instance Twitter just added support for this tech in the final 3 days on 2016.

One another thing that should be mentioned here is that; HTML5 video supplanting Flash entirely, and it is believed that Flash to pretty much bite the dust in 2017 except for free online games since its use is remaining quite widespread.

Next-generation video compression formats are likely to start hitting the mainstream, these next-gen formats include H.265 (HEVC) and AV1. H.265 delivers similar video quality at half the bitrate (and thus half the file size/data requirements) of H.264. AV1 aims to be more efficient than H.265, and is a royalty-free!

One more trend should be underlined here is that; both High Dynamic Range and High Frame Rate will become increasingly common. They are increasingly supported on 4K TVs and monitors that are becoming the default display technology.

H.265 (High Efficiency Video Coding - HEVC -)
According to x265.org H.265 and its benefits can be explained as follows:

> *"HEVC was developed with the goal of providing twice the compression efficiency of the previous standard, H.264 / AVC. Although compression efficiency results vary depending on the type of content and the encoder settings, at typical consumer video distribution bit rates HEVC is typically able to compress video twice as efficiently as AVC. End-users can take advantage of improved compression efficiency in one of two ways (or some combination of both);*
>
> - *At an identical level of visual quality, HEVC enables video to be compressed to a file that is about half the size (or half the bitrate) of AVC, or*
> - *When compressed to the same file size or bit rate as AVC, HEVC delivers significantly better visual quality.*
>
> *How can HEVC encode video files twice as efficiently as previous video coding standards?*

- *Most of the power of video compression standards comes from a technique is known as motion compensated prediction. Blocks of pixels are encoded by making reference to another area in the same frame (intra-prediction), or in another frame (inter-prediction). Where H.264/AVC defines macroblocks up to 16×16 pixels, HEVC can describe a much larger range of block sizes, up to 64 x 64 pixels.*
- *HEVC allows predicted blocks to be coded in different block sizes than the residual error. Each top level coding unit (or CTU) is first coded as a prediction quad-tree, where at each depth the encoder decides whether to encode with merge/skip, inter, or intra coding. The residual from those predictions is then coded with a second quad-tree which can optionally have greater depth than the prediction quad-tree. For instance, this allows the residual error from a 32×32 inter coded coding unit (CU) to be represented by a mixture of 16×16, 8×8, and 4×4 transforms.*
- *HEVC can encode motion vectors with much greater precision, giving a better predicted block with less residual error. There are 35 intra-picture directions, compared with only 9 for H.264/AVC.*
- *HEVC includes Adaptive Motion Vector Prediction, a new method to improve inter-prediction.*
- *An improved deblocking filter*
- *Sample Adaptive Offset – an additional filter that reduces artifacts at block edges"*

AV1

However, the documentation is not very clear while we are preparing this document, the following information could be found in the scientific literature:

> *"As already noted, the first version of AV1 was released by AOM in April 2016 [2.17]. To the best of the authors' knowledge and based on their analysis of the source code, AOM/AV1 (Version 1) is fully based on VP9. The only difference is that AOM/AV1 contains two additional in-loop filters, which are currently disabled by default. According to [2.18], the corresponding increase in coding efficiency (in terms of bit-rate savings), when enabling these filters, is expected to be in the region of 2.5%. However, when enabling these filters, this gain could not be verified by the authors of this paper due to a compilation error of the current AOM/AV1 code base. It should be noted that AOM/AV1 encoder has a two-pass coding option, which results in improved rate-distortion performance. So, this feature was enabled by the authors. Further, it should be noted that parallel processing in AOM/AV1 strictly relies on the usage of tiles, thereby implying a coding-efficiency penalty relative to the case where no tiles are used. As a consequence, multithreading in AOM/AV1 has been disabled in our experiments to not adversely affect its coding efficiency." [2.16]*

2.2. Supporting Technologies

2.2.1. Supporting Technologies in Public Transportation

Some of the supportive technologies of public transportation are explained below.

2.2.1.1 New Mobility Services Meet Public Transportation

The rise of technology, with the smartphone as the helm, is driving the shift away from urban mobility as a purely physical proposition. Alongside car-, bike-, and ride-sharing, the app-based Mobility as a Service (MaaS) and on-demand shuttle buses have emerged from their niche to address the needs of a wider audience.

At the same time, connected, autonomous vehicles (AV) are no longer on the horizon; they are testing on the roads now. On-demand mobility actors like Bridj and Careem have business models unlike those traditionally employed by the public transport sector. Acting as facilitators rather than direct service providers, their services are designed to be more reactive and flexible. They are not dependent on fixed routes, infrastructure or fleets. Conventional public transport, with its high capacity, is set to remain the transport backbone of cities.

However, the sector and authorities are realising they can up their game by learning lessons from new players. Local/regional transport authorities could, for example, procure such on-demand mobility services, which in certain cases would enable the provision of more efficient and/or less costly services than what currently exists. Ruter in Norway is already taking action by re-organising its service plan, while Transport for Greater Manchester is eyeing flexible on-demand mobility as a potential means of reducing the funding it pays out for supported services.
Mobility as a Service (MaaS), or 'integrated mobility platforms', seek to made it possible for travellers to combine and use diverse transport modes as simply as possible. While feedback to date is encouraging, experience from Smile in Vienna, UbiGo in Gothenburg, and the Hanover Mobility Shop reveal setting up and providing such services is no easy task. One of most salient issues being who should run them, and how? Planning long term strategy and day-to-day operations remain challenging. Financing for the extra cost generated by integration is still under debate.

2.2.1.2 (Re)Organisation Of The Public Transportation Market

In parallel to developments on the ground, the organisational structure of public transport is evolving, driven by the need to make service efficient for both operators and customers. Awareness of the economic role of public transport in cities has also grown.

The importance of a strong organising authority (PTA) is being confirmed across the globe, with leaders inspiring cities such as London, Singapore, Dubai or Moscow, followed more recently by Kuala Lumpur, Cape Town, and others adopting their own integrated organisational structures. Maintaining a durable vision of public transport when there is a change of government is also critical, as demonstrated by Vienna and Copenhagen. With less government support on offer, funding for these PTAs, however, remains a challenge. Hence they are continuing to explore and experiment with new revenue streams involving the private sector and business community.

Given local specificities, there is no one-size fits all when procuring services – competitive or in-house tendering, to contract or not to contract. Implementation of controlled competition depends largely on the presence/lack of a deregulated market or monopoly. Contracting is a confirmed trend, in diverse situations, with or without tendering for the provision of services Also at this organisational level, improvement can be observed in the areas of professionalism and quality, as well as a vision of mobility not only for decongesting cities, but for social, environmental, land use purposes and economic development too.

Some of the latest trends in digital signage include infotainment systems, which began to take hold in Europe, infotainment systems provide passengers visual information, utilizing LCD technology on transportation vehicles to display mapping, public service announcements, schedule changes and advertising. The types of advertising that are developing through infotainment are evolving as well. Systems now has the ability to provide location-based advertising, which uses GPS tracking. As the bus nears a specific retailer or restaurant, the infotainment system can display an advertisement on the screen about that particular company.

2.2.1.3 Information Kiosks

Additional trends in the digital signage arena include information kiosks. One advantage of this improvement would be that systems would allow trip planning via touch screen. The kiosk would generate an instructions on which buses and rail lines they can take to their destination along with travel times for the route.

2.2.1.4 Future Technologies

Companies are developing algorithms that will tell the passengers and transit employees exactly where buses and railcars are at any given time. This tools will be beneficial during an emergency situation, as the location information for the vehicle involved could be shared with fire and police departments quickly and easily. This technological development will require the integration of several systems onboard the vehicles, on the wayside and elsewhere.

Companies are also working toward an eco-friendly future with this technology by developing solar-powered wireless applications. Although these new products will help transit systems conserve energy, they are still undergoing testing.

2.2.1.5 Fossil Fuels and Beyond

As public transport continues its shift away from fossil fuels towards less polluting propulsion systems, awareness of the role oil prices and fuel subsidies are playing is growing. The Paris Climate Agreement has committed countries, which are now reviewing their strategy. Though the contribution of public transport to air pollution and greenhouse gas emissions is very low, we have now reached a point where alternative technologies like electric and hybrid buses are becoming more mature. This is confirmed by the move from symbolic and isolated pilots to more ambitious deployments, or plans (Paris, London, Stockholm, China) in this direction. A welcome development as part of the sector's contribution to tackling climate change, this step forward is, however, raising questions over the costs of charging infrastructure, fleet renewal, and upgrades. Standardisation, or the lack thereof, remains an ongoing issue. While electric is generally considered to be the way ahead over the long term, the technology is still not fully mature compared to a century of diesel bus development. Going forward, given their lower purchasing cost (more accessible for cities of all sizes) and good emissions performance, there will still be a role for Euro 6 buses.

2.2.1.6 The Motorcycle Boom

From Vietnam to Sub-Saharan Africa to Brazil, data confirms that lives and public health in cities are being challenged by the popularity of the motorcycle. Also, as urban space becomes increasing precious, the contribution of this mode of transport to traffic congestion and economic loss is also proving a major issue.

The success of efforts to curb and control (Hanoi, São Paulo, Indonesia, India), such as enforcing restrictions and licensing, depend very much on the importance of tackling the problem among authorities and decision makers. How high is it on their agenda? Policy planners need to think fast and consider strategies for shifting private car users to public transport before they turn to motorcycles instead. Yet unless a public transport system is sufficiently developed to absorb mobility demand for the immediate future at least, the motorcycle is set to remain a staple and essential transport mode.

As well as curbing private use, public authorities are also facing the challenge of incorporating the moto-taxi form of informal transport into an integrated and coherent transport supply. Going forward, electric motorcycles and organised shared services may well prove part of the solution. Already they are emerging.

2.2.1.7 Moving Forward...

With new actors, new business models and services, urban mobility is changing in line with our changing world. While remaining at the core of mobility in the city, public transport is adapting its form and functioning – not only to meet evolving customer demand and expectations, but also to reap the efficiency benefits on offer. Its role in the city as the backbone of the mobility system is not under threat, but must evolve to remain relevant. Changing citizen expectations, growing pressure on mobility demand (rising ridership), coupled with less public funding, implies new governance models.

The presence of organising entities to oversee networks will become crucial in the years to come, as will informed policy, long-term planning, and a stable vision. Public transport is at a turning point in a mobility market experiencing an important transition. In this context, it should take the leading role.

2.2.2. Supportive Technologies in Data Science

Some of the supportive technologies of data science are explained below.

2.2.2.1. MongoDB

MongoDB is a free and open-source document-oriented database program. It is one of the most popular NoSQL database programs. MongoDB uses JSON-like documents with schemas. MongoDB supports field, range queries, regular expression searches. Fields in a MongoDB document can be indexed with primary and secondary indices. MongoDB provides high availability with replica sets with two or more copies of the data. The data is split into horizontal ranges and distributed to multiple servers, balancing the load or duplicating data to keep the system up and running in case of hardware failure. MapReduce can be used for batch processing of data and aggregation operations. JavaScript can be used in queries, aggregation functions (such as MapReduce), and sent directly to the database to be executed.
MongoDB is useful when working with a huge quantity of data when the data's nature does not require a relational model. It is used in applications when what really matters is the ability to store and retrieve great quantities of data, not the relationships between the elements. In these cases MongoDB is typically performs several times better than classical relational DB systems.

2.2.2.2. Apache Kafka

Apache Kafka is an open-source stream processing platform. Its aim is to provide a unified, high-throughput, low-latency platform for handling real-time data feeds. Its storage layer is essentially a massively scalable pub/sub message queue architected as a distributed transaction log. Apache Kafka also connects to external systems (for data import/export) via Kafka Connect and provides Kafka Streams, a Java stream processing library.
Apache Kafka stores messages coming from arbitrarily many processes called "producers". The data can then be partitioned in different "partitions" within different "topics". Within a partition the messages are indexed and stored together with a timestamp. Other processes called "consumers" can query messages from partitions. Kafka runs on a cluster of one or more servers and the partitions can be distributed

across cluster nodes.
Apache Kafka efficiently processes the real-time and streaming data when used along with Apache Storm, Apache HBase and Apache Spark. Deployed as a cluster on multiple servers, Kafka handles its entire publish and subscribe messaging system with the help of four APIs, namely, producer API, consumer API, streams API and connector API. Its ability to deliver massive streams of message in a fault-tolerant fashion has made it replace some of the conventional messaging systems.

2.2.2.3. Apache Hadoop

Apache Hadoop is an open-source software framework used for distributed storage and processing of datasets of big data using the MapReduce programming model. It consists of computer clusters built from commodity hardware. All the modules in Hadoop are designed with a fundamental assumption that hardware failures are common occurrences and should be automatically handled by the framework.
The core of Apache Hadoop consists of a storage part, known as Hadoop Distributed File System (HDFS), and a processing part which is a MapReduce programming model. Hadoop splits files into large blocks and distributes them across nodes in a cluster. It then transfers packaged code into nodes to process the data in parallel. This approach takes advantage of data locality, where nodes manipulate the data they have access to. This allows the dataset to be processed faster and more efficiently than it would be in a more conventional supercomputer architecture that relies on a parallel file system where computation and data are distributed via high-speed networking.
The base Apache Hadoop framework is composed of the following modules:

- Hadoop Common – contains libraries and utilities needed by other Hadoop modules.
- Hadoop Distributed File System (HDFS) – a distributed file-system that stores data on commodity machines, providing very high aggregate bandwidth across the cluster.
- Hadoop YARN – a platform responsible for managing computing resources in clusters and using them for scheduling users' applications.
- Hadoop MapReduce – an implementation of the MapReduce programming model for large-scale data processing.

2.2.2.4. Neo4j

Neo4j is an ACID-compliant transactional graph database management system with native graph storage and processing feature. It is one of the most popular NoSQL database systems and the most popular graph database system.
Neo4j is implemented in Java and accessible from software written in other languages using the Cypher Query Language through a transactional HTTP endpoint, or through the binary "bolt" protocol.
In Neo4j, everything is stored in the form of either an edge, a node, or an attribute. Each

node and edge can have any number of attributes. Both the nodes and edges can be labelled. Labels can be used to narrow searches.

2.2.3. Supportive Technologies in Multimedia Streaming

Some of the supportive technologies of multimedia streaming are explained below.

2.2.3.1 Nginx Web Server

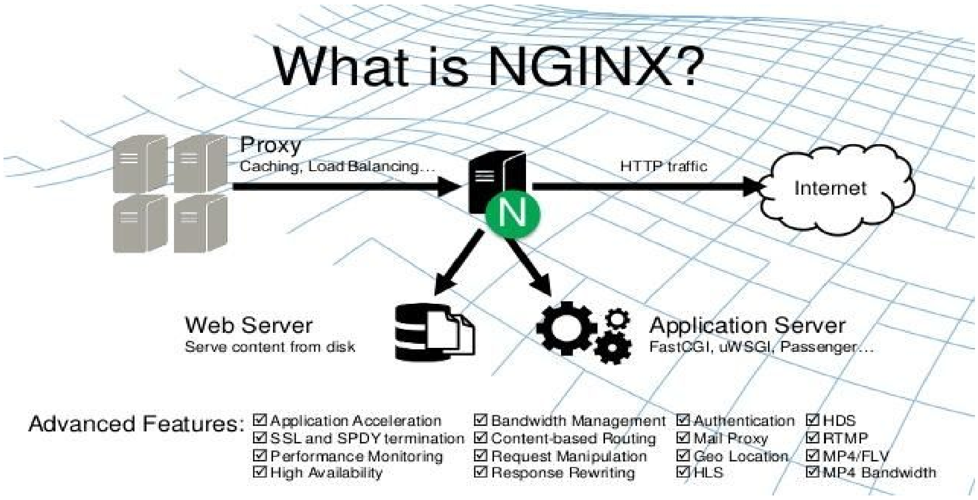

Figure 5 : Nginx [2.19]

Nginx is an open source HTTP Web server and reverse proxy server for HTTP, HTTPS, SMTP, POP3, and IMAP protocols, as well as a load balancer and an HTTP cache, Nginx can also operate as an IMAP/POP3 mail proxy server as well as function as a load balancer and HTTP cache server. Nginx runs on Linux, Mac OS X, Solaris, AIX, HP-UX and BSD variants and pronounced as "Engine-Ex" Nginx has emerged as the third most popular Web server behind the Microsoft's IIS, Apache Web server. Nginx powers popular websites like Netflix, WordPress.com, Pinterest and Zynga. Nginx can be deployed to serve dynamic HTTP content on the network using FastCGI, SCGI handlers for scripts, WSGI application servers or Phusion Passenger modules, and it can serve as a software load balancer. "Nginx uses an asynchronous event-driven approach to handling requests, similar to Apache HTTP Server Event MPM model. Nginx's modular event-driven architecture can provide more predictable performance under high loads. [2.20]"

2.2.3.2. Wowza Streaming Engine

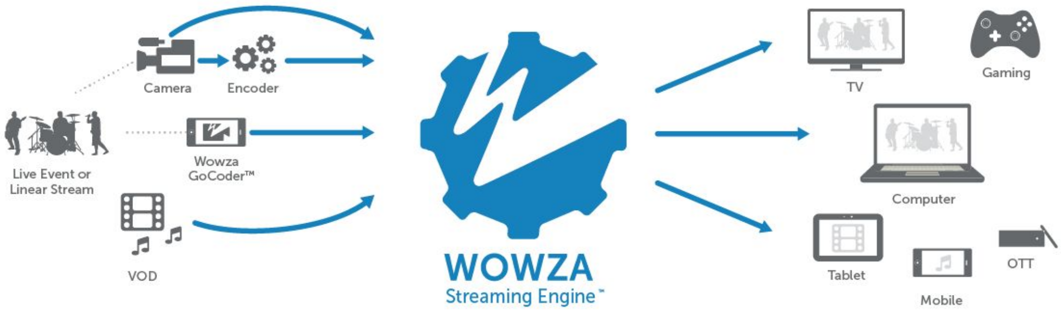

Figure 6 : Wowza [2.24]

Wowza Streaming Engine is a combined streaming media server software." Servers used for live and on-demand video streaming, desktop, laptop and tablet computers, mobile devices, IPTV set-top boxes, Internet-connected TVs, game sounds and rich Internet applications over IP networks for consoles, and other networked devices. [2.21]" A Java application servers can be deployed on multiple operating systems.
Wowza Streaming Engine can stream to multiple types of playback clients and devices simultaneously, including the Adobe Flash player, Microsoft Silverlight player, Apple QuickTime Player and iOS devices (iPad, iPhone, iPod Touch), 3GPP mobile phones, IPTV set-top boxes (Amino, Enseo, Roku, Streamit and others), and game consoles such as Wii, Xbox, and PS3.
"Wowza Streaming Engine can stream to multiple types of playback clients and devices simultaneously, including the Adobe Flash player, Microsoft Silverlight player, Apple QuickTime Player and iOS devices (iPad, iPhone, iPod Touch), 3GPP mobile phones, IPTV set-top boxes (Amino, Enseo, Roku, Streamit and others), and game consoles such as Wii, Xbox, and PS3. [2.21]"

2.2.3.3. FFmpeg

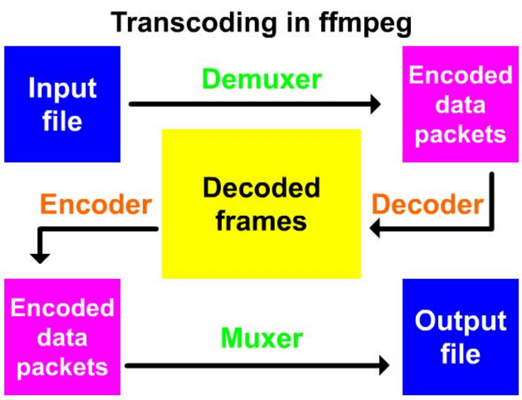

Figure 7 : Ffmpeg[2.23]

FFmpeg is a free software project that produces libraries and programs of handling multimedia data and it is the leading of multimedia framework, able to decode, encode, transcode, stream, filter, libavcodec, an audio/video codec library used by several other projects, libavformat, an audio/video container mux and demux library, the ffmpeg command line program for transcoding multimedia files and play anything. FFmpeg is also highly portable: FFmpeg compiles, runs. It passes our testing infrastructure FATE across Linux, Mac OS X, Microsoft Windows, the BSDs, Solaris under a wide variety of build environments, machine architectures and configurations. "The FFmpeg project tries to provide the best technically possible solution for developers of applications and end users alike. To achieve this we combine the best free software options available. [2.22]"

List of Figures

List of Tables

References

1.1. Mark Vallianatos. June 16,2015. Uncovering the Early History of "Big Data" and the Smart City in Los Angeles. Retrieved from:

https://boomcalifornia.com/2015/06/16/uncovering-the-early-history-of-big-data-and-the-smart-city-in-la/

1.2. Wikipedia Contributors. Wikipedia, The Free Encyclopedia. January 31, 2018, "Smart City" Retrieved from:

https://en.wikipedia.org/w/index.php?title=Smart_city&oldid=823259830

1.3. Essays, UK. November, 2013. The History Of Smart Cities Concept Information Technology Essay. Retrieved from:

https://www.uniassignment.com/essay-samples/information-technology/the-history-of-smart-cities-concept-information-technology-essay.php?cref=1

1.4. Wikipedia Contributors. Wikipedia, The Free Encyclopedia. January 31, 2018, "Smart City" Retrieved from:

https://en.wikipedia.org/w/index.php?title=Smart_city&oldid=823259830

1.5. Wikipedia Contributors. Wikipedia, The Free Encyclopedia. January 31, 2018, "Smart City" Retrieved from:

https://en.wikipedia.org/w/index.php?title=Smart_city&oldid=823259830

1.6. Kian Goh. May 21, 2015. Who's Smart? Whose City? The Sociopolitics of Urban Intelligence. In: Geertman S., Ferreira, Jr. J., Goodspeed R., Stillwell J. (eds). *Planning Support Systems and Smart Cities.* Lecture Notes in Geoinformation and Cartography. Springer, Cham. Retrieved from:

https://link.springer.com/chapter/10.1007%2F978-3-319-18368-8_9

1.7. Brian Deal, Varkki Pallathucheril, Yong Wook Kim and Haozhi Pan. 2015. Sentient PSS for Smart Cities. In: Geertman S., Ferreira, Jr. J., Goodspeed R., Stillwell J. (eds) *Planning Support Systems and Smart Cities.* Lecture Notes in Geoinformation and Cartography. Springer, Cham. Retrieved from:

https://link.springer.com/chapter/10.1007/978-3-319-18368-8_15

1.8. Russell Bond, Ammar Kanaan. 2015. MassDOT Real Time Traffic Management System. Geertman S., Ferreira, Jr. J., Goodspeed R., Stillwell J. (eds). In *Planning Support Systems and Smart Cities* (pp. 471-481) MIT,Boston. Retrieved from:

https://books.google.com.tr/books?id=uG-nCQAAQBAJ&pg=PA471&dq=Ammar+Kanaan+are+pursuing+an+innovative+business+model+that+provides&hl=tr&sa=X&ved=0ahUKEwjZv8GugJbZAhXMiSwKHStDBQUQ6AEIJjAA#v=onepage&q=Ammar%20Kanaan%20are%20pursuing%20an%20innovative%20business%20model%20that%20provides&f=false

1.9. Juan Rico. 2014. Technology Improvements for Large-Scale Smart City Deployments. Retrieved from:

https://www.eurescom.eu/news-and-events/eurescommessage/eurescom-message-2-2014/celtic-project-tilas.html

1.10. Project 15018: CitiSim, Smart City 3D simulation and monitoring platform. Retrieved from:

https://itea3.org/project/citisim.html

1.11. Project: 15022: MOS2S, Media Orchestration-Sensor to Screen. Retrieved from:

https://itea3.org/project/mos2s.html

1.12. Accelerating and Rescaling Transitions to Sustainability. Retrieved from:

http://acceleratingtransitions.eu/

1.13. Smart Cities Information Center: Aachen. Retrieved from:

http://smartcities-infosystem.eu/countries-and-cities/aachen

1.14. Kiviluoto, K., Kunnasvirta, A., Mieskonen, T., Ek, L., Haselberger, J., Kullman, M,. Meijers, E.J.. 2016. Green Thoughts, Green Futures: Planning for Energy Efficient Cities. Retrieved from:

https://repository.tudelft.nl/islandora/object/uuid%3Ad9dc4234-64de-4338-8818-13447ee9f581

1.15. ICT Roadmap and Data Interoperability for Energy Systems in Smart Cities. *READY4SmartCities.* April 22,2017. Retrieved from:

http://cordis.europa.eu/project/rcn/110042_en.html

1.16. European Commision, CORDIS. September 2016. EPIC European Platform for Intelligent Cities. (pp.1-2) Retrieved from:

http://www.epic-cities.eu/sites/default/files/documents/EPIC%20fact%20sheet%20EC_0.pdf

1.17. European Commision, CORDIS. April 25,2017. Live Video-to-Video Supporting Interactive City Infrastructure. Retrieved from:

https://www.cordis.europa.eu/project/rcn/191925_en.html

1.18.European Commision, CORDIS. Pilot Smart Urban Ecosystems Leveraging Open İnnovation for Promoting and Enabling future E- Services. April 25,2017. Retrieved from:

https://www.cordis.europa.eu/project/rcn/191925_en.html

1.19. Eureka. Intelligent Urban Traffic Control System. Retrieved from:

http://www.eurekanetwork.org/project/id/6794

1.20. Eureka. Narrowband Wireless Video Surveillance System. Retrieved from:

http://www.eurekanetwork.org/project/id/5379

1.21. Eureka. “Safe Roads”. Automatic Real Time System for Traffic Security and Violation Detection in Roads. Retrieved from:

https://www.eurostars-eureka.eu/project/id/8217

1.22. Era-Learn. Fully Automated Traffic Management System for Road Works. Reference No: FAcTuM 8175 Retrieved from:

https://www.era-learn.eu/network-information/networks/eurostars/cut-off-05-03-2015/fully-automated-traffic-managment-system-for-road-works

1.23. Era-Learn. Sights on Recommendation Engine. Reference No: SIREN 6554 Retrieved from:

https://www.era-learn.eu/network-information/networks/eurostars/eurostars-programme/sights-on-recommendation-engine

1.24. Eurostars. SECAIR, Security on Airport and Other Critical Large Infrastructure. Retrieved from:

https://www.eurostars-eureka.eu/project/id/6030

1.25. Project ASUA. Advanced Sensing for Urban Automation. Retrieved from:

https://www.celticplus.eu/project-asua/

1.26. Eureka Project 9172 MONET

1.27. Eureka. Advanced Security & Threat Detection System. Retrieved from:

http://www.eurekanetwork.org/project/id/7178

1.28. Eureka. Intelligent Urban Traffic Control System. Retrieved from:

http://www.eurekanetwork.org/project/id/6794

1.29. Eurostars. New system for a complete, automatic, real-time identification of ground vehicles. Retrieved from:

https://www.eurostars-eureka.eu/project/id/5012

1.30. EUREKA EICS E! 5381. Retrieved from:

http://teb-css.hr/en/services/research-development/eureka-eics-e-5196/

1.31. Eureka Project 6252 X-NETAD

1.32. Interoperable Smart City Services through an Open Platform for Urban Ecosystems. Retrieved from:

http://www.iscopeproject.net/

1.33. CITY Keys. Retrieved from:

http://www.citykeys-project.eu/

1.34. European Commision, CORDIS. April 25, 2017. BRISEIDE, Bridging Services, Information and Data for Europe. Project ID: 250474. Retrieved from:

https://cordis.europa.eu/project/rcn/191716_en.html

1.35. Matthias Stevens. June 2012. Community Memories for Sustainable Societies. Vrije Universiteit, Brussel. Retrieved from:

http://discovery.ucl.ac.uk/1368079/1/1368079_Thesis-final.pdf

1.36.European Commision, CORDIS. May 25,2017. i-TOUR: Intelligent Transport system for Optimized Urban Trips. Project ID: 234239 Retrieved from:

https://cordis.europa.eu/project/rcn/93951_en.html

1.37. Rapid Deployment for Intelligent Cities and Living. Retrieved from:

http://www.radical-project.eu/

1.38. Ozan Tonguz, Wantanee Viriyasitavat. September 18, 2014. Methods and Software for Managing Vehicle Priority In A Self-Organizing Traffic Control System. Carnagie Mellon University. Patent No: US 20140278029 A1 Retrieved from:

https://www.google.com/patents/US20140278029

1.39. Boris Goldstein. October 27, 2011. Method and System for an Integrated Safe City Environment Including E-City Support. Patent No: US 20110261202 A1 Retrieved from:

http://www.google.ch/patents/US20110261202

1.40. Lim Keun Won. March 30, 2016. The Outdoor Advertising Products and How to Manage Outdoor Signage Census Using Smartphone. Patent No: KR20160034754 Retrieved from:

https://goo.gl/0nU97C

1.41. Curtis E. Ford, Drew Cartwright. December 29,2015. Emergency Digital Sign Network with Video Camera, Methods of Operation, and Storage Medium. Patent No: US9221385 B2. Texas Emergency Network, LLC. Retrieved from:

http://www.google.ch/patents/US9221385

1.42. Li Fangquan. February 24, 2016. Outdoor Advertisement Transfer Membrane Technology. Patent No: CN105355157 Retrieved from:

https://worldwide.espacenet.com/publicationDetails/biblio?FT=D&date=20160224&DB=EPODOC&locale=en_EP&CC=CN&NR=105355157A&KC=A&ND=5

1.43. Ju Young Gi. January 19,2016. Outdoor Advertising Panel Structure. Patent No: KR20160006505 Retrieved from:

https://goo.gl/sUavuh

1.44. Taki Hisao. February 08, 2016. Advertisement Distribution System. Patent No: JP2016024386 (A). Retrieved from:

https://goo.gl/mzKaRu

1.45. Liu Jianyong. February 03, 2016. Novel Outdoor Billboard. Patent No: CN205016198 Retrieved from:

https://goo.gl/sPqWwS

1.46. Kim Gi Bog, Kang Nam Won. December 11,2015. Display Apparatus for Outdoor Advertisement with Heating Function. Patent No: KR20150139215. Retrieved from:

https://goo.gl/yNCzCP

1.47. Chapman Craig H., Parikh Kush G., Downs Oliver B., Cahn Robert C., Hersch Jesse S.. June 14, 2012. Determining Road Traffic Conditions Using Multiple Data Samples. Patent No: US 2012150425 (A1) Retrieved from:

https://goo.gl/76Ts1j

1.48. Nadeem Tamer M., Loiacono Michael T.. April 28, 2011. Mobile Sensing for Road Safety, and Road Maintenance. Patent No: US 2011095908 (A1) Retrieved from:

https://goo.gl/vLSZjZ

1.49. Lemelson Jerome H., Lemelson Dorothy, Pedersen Robert D., Pedersen Steven R.. January 24, 2002. Intelligent Traffic Control and Warning System and Method. Patent No: US 2002008637 (A1). Retrieved from:

https://goo.gl/wB2wZd

1.50. Strategyr.com, September,2017. Inherent Interactive Storytelling and Targetability Capabilities Drive Global Investments in Outdoor Advertising. Retrieved from:

http://www.strategyr.com/Carotenoids_Market_Report.asp

http://www.strategyr.com/MarketResearch/ViewInfoGraphNew.asp?code=MCP-1610

1.51. Billboard and Outdoor Advertising Market-Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2015-2023. Retrieved from:

https://www.transparencymarketresearch.com/billboard-outdoor-advertising-market.html

1.52. Wikipedia Contributors. Wikipedia, The Free Encyclopedia. February 6, 2018, “Intelligent Transportation System”. Retrieved from:

http://www.wikizero.info/index.php?q=aHR0cHM6Ly9lbi53aWtpcGVkaWEub3JnL3cvaW5kZXgucGhwP3RpdGxlPUludGVsbGlnZW50X3RyYW5zcG9ydGF0aW9uX3N5c3RlbSZvbGRpZD04MjQyODgxOTI

1.53. Intelligent transport systems — Cooperative systems — State of the art of Local Dynamic Maps concepts, ISO/TR 17424:2015. Retrieved from:

https://www.iso.org/standard/59722.html

1.54. Ministry of Land, Infrastructure, Transport and Tourism, "ITS yogo shu", Last accessed at: 6 November 2014. Retrieved from:

http://www.iatss.or.jp/common/pdf/en/publication/commemorative-publication/iatss40_theory_05.pdf

1.55. Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010. eur-lex.europa.eu. Retrieved from:

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:207:0001:0013:EN:PDF

1.56. Intelligent Transport Systems, T. Hasegawa, Professor, Division of Mathematics, Electronics and Informatics, Saitama University.

1.57. ITS- Intelligent Transport Systems. Retrieved from:

https://boschung.com/en/products/intelligent-transport-system

1.58. Cooperative Intelligent Transport Systems and Services, The European Innovation Partnership on Smart Cities and Communities, 2013.

1.59. Intelligent Transport Systems in Action, Action Plan and Legal Framework for the Development of ITS in Europe, European Commission, Directorate General for Mobility and Transport, 2011.

2.1. Jeffrey L. Western, Bin Ran. 2000. Information Technology in Transportation: Key Issues and a Look Forward. (Pg. 5) . *Transportation in the New Millennium.* Retrieved from:
http://onlinepubs.trb.org/onlinepubs/millennium/00054.pdf
2.2. International Data Corporation.
http://www.idc.com/home.jsp
2.3. Wikipedia Contributors. Wikipedia, The Free Encyclopedia. February 9,2018. "Big Data". Retrieved from:
http://www.wikizero.info/index.php?q=aHR0cHM6Ly9lbi53aWtpcGVkaWEub3JnL3cvaW5kZXgucGhwP3RpdGxlPUJpZ19kYXRhJm9sZGlkPTgyNDYzNzI3Nw
2.4 Wikipedia Contributors. Wikipedia, The Free Encyclopedia. February 9,2018. "Data Science". Retrieved from:
https://en.wikipedia.org/wiki/Data_science
2.5 X. Amatriain, A. Jaimes, N. Oliver, and J. M. Pujol, "Data Mining Methods for Recommender Systems", Recommender Systems Handbook
2.6 Wikipedia Contributors. Wikipedia, The Free Encyclopedia. February 9,2018. "Data Analysis". Retrieved from:
https://en.wikipedia.org/wiki/Data_analysis
2.7 Techopedia. Data Analytics. Retrieved from:
https://www.techopedia.com/definition/26418/data-analytics
2.8 Margaret Rouse. June 2017. Machine Learning. Retrieved from:
http://whatis.techtarget.com/definition/machine-learning
2.9 Wikipedia Contributors. Wikipedia, The Free Encyclopedia. February 9,2018. "Data Mining". Retrieved from:
https://en.wikipedia.org/wiki/Data_mining
2.10 Anmol Rajpurohit. Interview:David Kasik, Boeing on Data Analysis vs. Data Analytics. Retrieved from:
http://www.kdnuggets.com/2015/02/interview-david-kasik-boeing-data-analytics.html
2.11 Robert D. Hof. 2013. Deep Learning. *"MIT Technology Review"* Retrieved from:
https://www.technologyreview.com/s/513696/deep-learning/
2.12. Tracy V. Wilson. October 12, 2007."How Streaming Video and Audio Work". Retrieved from:
https://computer.howstuffworks.com/internet/basics/streaming-video-and-audio.htm
2.13. "Modern Video Streaming in the Enterprise: Protocols, Caching, and WAN Optimization", Panopto, White Paper, 2015.
2.14. "Enterprise and Broadcasting Video Trends in Europe", International Data Corporation, 2017.
2.15. "Video Streaming Software Market, Global Forecast to 2022, An Executive Summary", MarketsandMarkets, 2017.
2.16. D. Grois, T. Nguyen, D. Marpe, Fellow, "Coding Efficiency Comparison of AV1/VP9, H.265/MPEG-HEVC, and H.264/MPEG-AVC Encoders", PCS 2016.
2.17. Alliance for Open Media, git repository online at: https://aomedia.googlesource.com/aom
2.18. J.-M. Valin, "Directional Deringing Filter", Internet Draft, Network Working Group, Internet Engineering Task Force, 2016.
2.19. Ajit Punchhi. December 31,2015. Nginx Web Server and its features #Nginx #Webserver. Retrieved from:
https://www.linkedin.com/pulse/nginx-web-server-its-features-webserver-ajit-punchhi
2.20. Forest Stroud. Nginx. Retrieved from:
http://www.webopedia.com/TERM/N/nginx.html
2.21. Vangie Beal. Web-Scale IT. Retrieved from:
http://www.webopedia.com/TERM/W/web-scale-it.html
2.22.https://ffmpeg.org/about.html
2.23.http://ffmpeg.tv/
2.24.http://mediacast.vn/san-pham/1728/phan-mem-streaming-wowza-streaming-engine.html