Convergence in Smart Cities

In Partnership with Smart Dubai

دبـــي الذكية
SMART DUBAI

Building the Digital Infrastructure for the Fourth Industrial Revolution

Outlier Ventures

Contents

Foreword: Jamie Burke

At Outlier Ventures we believe the convergence of technologies like blockchain, Internet of Things (IoT) and Artificial Intelligence (AI) will accelerate a new Web. One that is more decentralised, peer-to-peer, automated and increasingly autonomous. A place in which people, machines and their agent-based digital representatives exchange value in a frictionless way to organize and optimize the world around us.

This vision, whilst exciting, raises many practical and ethical questions, none more so than how these systems are governed to serve and empower their citizens, rather than just a handful of large global corporations. Since our very inception, we have seen smart cities as innovation centers and a testbed to experiment at the very edge of possibility - but also as living, breathing places to socialize these technologies for the betterment of the lives of citizens in a measurable way.

This paper is the beginning of an exciting partnership between Smart Dubai and the Convergence Stack. We at Outlier have been sharing this vision with the world for some time, and now we are making it a reality at scale with smart city. Dubai wants to be a world leader in the real-world deployment of convergence technologies. More importantly, Smart Dubai are brave enough to not just take the easy route. Smart Dubai recognises that startups and people challenging the status quo are central to championing a new, more decentralised data stack, centered around the sovereignty of individuals and their data.

We are honoured to share this journey with the Smart Dubai team and leadership and hope to inspire other cities around the world to join us in this mission.

Foreword: Smart Dubai

Smart Dubai's mission is to create the happiest city on earth. Our day-to-day business is to constantly challenge and re-conceptualize the city and its service landscape. For our communities, our businesses, international trading partners and visitors, we want to leverage the seemingly limitless potential of technology, and more specifically data, to maximize innovation potential and value creation.

We are hugely excited about the partnership we are building with Outlier Ventures. This report signals the start of a collaboration that will see us explore - carefully and with confidence - the frontiers of decentralised approaches that will allow for the secure, privacy-protecting, efficient, and value-based exchange of data.

We want to move forward through a process that will provide the open and collaborative innovation ecosystem demanded by emerging technologies and the optimized smart city.

This is no easy task. It is one that, to be successful, must be based on collaboration, connection, and convergence, as well as technology. This is what excites us about the convergence stack that Outlier Ventures brings together. It recognizes how data is collected, transported and exchanged in marketplaces that function both economically and for technology innovation that consists of many moving parts. It is by bringing these elements together that we will create value and investable urban business models.

This exploration we are embarking upon is backed by a track record of delivery against ambition. As a city government innovation accelerator, Smart Dubai has implemented ground-breaking strategies to drive blockchain implementation in city services and the digitization of public services to dramatically reduce paper and bureaucracy. We have our own AI Lab, and through our Ethical AI Assessment Tool provide an adaptive regulatory framework to encourage the proper application of this exciting technology. Data flowing in ever greater volumes across a decentralised data stack and traded in markets will add a significant complement the centralised approach of today, and help make a reality of AI.

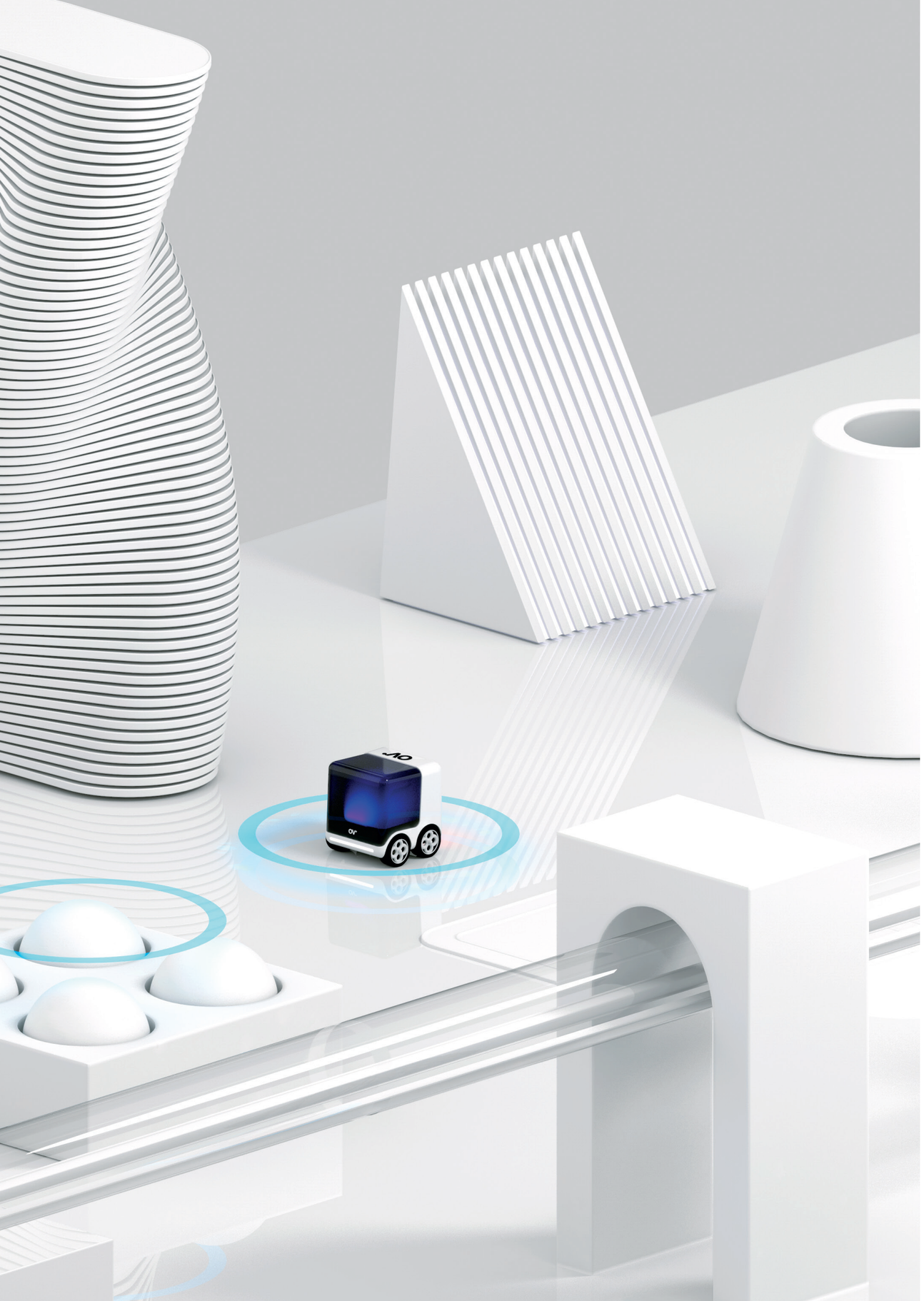
Smart Dubai is also offering to facilitate secure payment and self-sovereign identification through Dubai Now and the national UAE Pass respectively, as we see this as a vital step towards the future data economy.

Tying all this together is our Private Sector Data Strategy - backed by comprehensive data laws and policies - which sets out how we will exercise active stewardship of the city data economy, and which contains a specific commitment to explore decentralised technologies.

Smart Dubai will be a convening agent in this ecosystem. We will work with the innovative businesses, society, and government to complete the decentralised stack. From governance to data exchange protocols and underpinning architectures, to use case development that will provide the evidence base for future data markets and economic segments like the sharing economy - we will be at the forefront of innovation in this space. We set out later in this report a series of key activities, to take place this year, which will allow us to take the words of the page and start to make real decentralised data approaches in Dubai.

I want to finish with the saying "a problem shared is a problem halved". But I also offer a mirror version - "an opportunity shared is an opportunity maximised". Both are true in an appreciation of how decentralised data exchange can drive future data value and how we cannot act alone in pursuit of it.

— Younus Al Nasser
CEO Smart Dubai Data



Executive Summary

Building the digital infrastructure for the Fourth Industrial Revolution

As our greatest challenges become increasingly global, and technological progress continues its exponential march, cities are once again coming to the fore. Nations are struggling to address global challenges like climate change, migration, and an integrated global economy supercharged by the Internet. Cities do not suffer from the same level of constitutional weight and are able to be more flexible and adaptable to the fast-changing technological, cultural and economic landscape. As the scale of emerging and present threats are presented globally, such as climate change and migration, the nation is no longer able to deliver effective policy responses.

Cities, on the other hand, offer a solution, as they reinforce collaboration and globalism to tackle these global problems regardless of national borders. It is the city that has the flexibility and opportunity to grasp the opportunities emerging from the coming Fourth Industrial Revolution and make a real and lasting impact. Cities must lead the revolution by utilizing data and emerging technologies in an open, collaborative, and shared way to build the digital infrastructure required to support a global, integrated and dynamic economy.

Renewal of the city

By 2050, 68% of the world's population will live in cities. These megacities will be producing more than 80% of the global Gross Domestic Product (GDP) and will come to resemble the ancient state-cities of Athens, Rome, and Carthage - but this time round, they will be fueled by data. These poles of attraction tend to have similar challenges to nations around infrastructure, connectivity, mobility, and healthcare and have developed their own distinct cultural and economic micro-climates. Broken business models and misaligned incentives between different city stakeholders have restrained innovation and limited sustainable and inclusive growth.

Public-private partnerships are a start and have fostered collaboration between corporations and governments by aligning the business models while ensuring solutions meet the needs of citizens, not just shareholders. Cities, just like communication networks, benefit from network effects - the more citizens join, the more collaboration, innovation and economic output it produces. The challenge comes in connecting people, assets and data to take advantage of these city network effects.

Data at the heart of city renewal

The amount of data created annually will reach 180 zettabytes by 2025, up from 4.4 zettabytes in 2013. A zettabyte is approximately equal to a billion terabytes; this amount of data isn't merely 'big', it is colossal. The average person will interact with connected devices every 18 seconds (nearly 4,800 times a day) in six years' time. IoT

devices surpassed the number of humans in 2017 and are expected to reach 20.4 billion by 2020. Data is the single most important resource for the economy of the future and to create a level playing field, we have to break current data silos that lead to an asymmetric advantage and stifle innovation. The free flow of data is imperative for collaboration, innovation, and fairer economic relationships. It comes in the form of strong cryptography, distributed ledgers, and crypto-tokens that provide the backbone for a secure, auditable and peer-to-peer digital infrastructure.

Decentralised data exchanges give value to data

A handful of cities such as London, New York, Barcelona and Singapore have led the way on open data and data utilization. Dubai specifically has been at the forefront of ecosystem-wide approaches that encourage the sharing of data from both public, and more recently with the activation of its Private Sector Data Strategy, private sector entities.

It will be the combination of open data frameworks with distributed ledgers and decentralised data exchanges that will finally provide the infrastructure for data to have real value beyond a select few aggregators. Users, companies and governmental bodies will be able to manage, buy, sell and rent data. We will see the emergence of a whole host of new marketplaces beyond today's basic cryptocurrency exchanges. These marketplaces will cover sensor data, personal data and data for AI algorithms, for example. Users can also exchange digital goods of any kind, such as virtual land on a virtual reality world, bots that perform certain actions and other crypto-assets. Smart cities are the ideal places for these marketplaces to take root - it is here that we will find a vast ecosystem of interlocking data markets from energy, transport, buildings, and physical infrastructure.

The Convergence Stack in smart cities

We need to build out from existing centralised digital infrastructure if we are to achieve this potential, and mitigate technical and more far-reaching economic and social problems. Outlier Ventures believes the Convergence Stack offers a valuable framework for understanding and building the next phase of digital infrastructure in cities. Smart Dubai understands the need to explore this 'whole stack' approach - from governance to market mechanisms, to the underpinning technologies - at the heart of the Convergence Stack.

In the Convergence Stack, data is the core asset. Covering hardware, software, networking and applications, the stack underpins a private, secure, and decentralised digital infrastructure all coordinated by crypto-tokens. This new infrastructure requires a host of technologies from the hardware to secure the data to the tools to distribute the data like distributed ledgers. It will also need new routing and authentication technologies, interfacing technologies to make it easier to build applications, and new services, marketplaces and applications for users to benefit from what we hope to be a more equitable digital infrastructure.

As cities become the preeminent arena for economic growth and global problem-solving, we expect to see city-states lead to the development of digital infrastructure to support the Fourth Industrial Revolution.

The Convergence Stack offers a blueprint on how cities are not just smart, but successful.

Part 01

Designing a Successful and Humanised Smart City

Human need at the top of the hierarchy

When most people think of a smart city they picture a gleaming city full of skyscrapers with intelligent systems, autonomous drones, cars, and robots collecting and processing data in real-time as the speed us to our next meeting or deliver us our pizza.

To some extent, visions of the future are coming true with drone delivery and autonomous cars on the horizon, but what is often lost with this vision of the future is how it will enable us to thrive and live happy and meaningful lives. The Global Happiness Council, a think tank headed by the authors of the UN's World Happiness Report, recently published the Global Happiness and Wellbeing Policy Report highlighting the work one of its sub-councils, Happy Cities, which is led by Smart Dubai and firmly places happiness and well-being at the center of city design.

Smart Dubai also leads the UN Council for SDG 11 (Sustainable Cities and Communities), focussed as it is on city development for real-world change and outcomes across economic, environmental and societal factors all supported, and not led, by technology.

Figure 1. Smart City Ecosystem © Outlier Ventures

The global smart cities market is projected to grow from just over $529 billion in 2017 to nearly $2 trillion by the end of 2023[1]. Of course, smart cities are not just one single measurable market nor one single definition; they are in fact, a complex web of interrelated markets and technologies, each with their own drivers and restraints to adoption. That said, the speed of deployment and growth of smart cities has more to do with government drive and political capital than it does with technological factors. Therefore the roll-out of smart cities won't be consistent across continents or even countries, it will resemble more a global patchwork of forward-thinking cities and city leaders.

Public-private partnerships, renewable energy, access over ownership and new data business models are driving smart city development

Public-private partnerships aligning incentives

The smart city industry is witnessing different forms of investment scenarios, such as Build Operate Transfer (BOT), Build Operate Manage (BOM), and Build Operate Own (BOO), which are gaining traction as funding models for cities. The BOM model for investment and management is gaining popularity due to its ease of operation and a combined control over the infrastructure it offers to interested parties. Public-private partnerships utilizing these models create a win-win scenario. Corporates benefit from having a clear financial incentive, sharing resources and expertise with the city, as well as a boosted reputation. Government bodies and citizens benefit from enjoying state of the art technology solutions, outsourced technical maintenance, reduced costs, and job market stimulation.

Renewable energy sources turn consumers into prosumers

Rapid advancements in technology and huge cost reduction in harnessing, storing, managing and distributing renewable energy sources - especially solar, are turning energy into a commodity and unlocking new data-driven value and business models. Energy consumers are becoming producers (prosumers) and have the ability to store and exchange energy in a peer-to-peer manner via transactive smart grids. Two key emerging models are "Energy as a Service" and "Energy Storage as a Service".

Access over ownership extends further than mobility

Electrification, autonomy, and access-over-ownership are reshaping every part of the industry and moving it into a new era of integrated mobility. This is the concept of a seamless transit experience incorporating multimodal, public and private transport. Not only are we moving away from owning vehicles, but also owning houses and other assets. The X-as-a-Service model can reduce costs, and improve efficiency and flexibility. As this model spreads across a wide range of services, we are getting closer to City as a Service.

Data unlocks latent economic value

The massive deployment of the IoT including chips, sensors and actuators in combination with the digitization of services, results in the creation and collection of massive amounts of data. By processing and analyzing data, we can transform data-driven value to data-driven business models and services. Numerous city governing bodies are opening up their data and are inviting corporations, citizens and entrepreneurs to utilise it, come up with innovative solutions and create digital wealth.

[1] Reuters.com. (2018). Global Smart cities Market Size and Trends – Industry Analysis by Key Developments, Players, CAGR Growth Projection to 2023 - Reuters. [online] Available at: https://www.reuters.com/brandfeatures/venture-capital/article?id=30881.

Aligning incentives, resolving conflict over data ownership and utilizing security to unleash growth

Aligning incentives

A lack of solid business models and misaligned incentives have been slowing the development of smart city initiatives for a long time. Governments by their very nature do not have profit as a top priority but businesses, especially large businesses required for large scale city infrastructure programs, need to have clear return-on-investment numbers and a solid business model.

This is particularly challenging in the smart city space, as the buyers of city or public services typically indirectly purchase through local or national taxes. Buyers need to be constantly alert to the distortions created by focussing too keenly on reducing short-term costs rather than increasing service levels or long-term sustainability. Further challenges are presented by the lack of funding and expertise in many city governments to implement complex long-term smart city projects. This is exacerbated by the fact the technology is new and the skills in which to take advantage of the technology take longer to reach the public sector.

Confusing data ownership and data silos

The big challenge across an ever-increasing range of industries and value chains is ownership of data. Not just from a personal privacy perspective, but also between organizations. At the moment, private companies are controlling data in vast quantities, but as it slowly dawns on cities that this data is the lifeblood of public services, they are pressing for change. Transport for London has suggested it is considering forcing private hire operators like Uber to share data as part of new licensing regulations, while Airbnb is taking the City of New York to court so it doesn't have to share hosts' names and addresses.

It is not yet clear who owns the ever-increasing amount of data that is being created by and for the city. For example, in a drone delivery scenario: is it the user of a drone delivery service? The creator of the drone delivery service? The owner of the drone themselves? The owner of the spectrum? Or the city council? The same questions need to be answered for all public services and spaces, and increasingly private spaces like homes. Arriving at answers to questions like these will release full smart city development potential.

Security in the city

Major hindrances in the adoption and implementation of these technologies include concerns regarding privacy and security of data. Devices connected to the Internet, or so-called 'IoT' devices are vulnerable. As services such as healthcare and mobility get connected, security becomes life-threatening and not just an issue for the Chief Information Officer. As it stands, getting your Facebook or Amazon account hacked even though frustrating, is unlikely to threaten your life. Getting your autonomous vehicle, heart pacemaker, or a genome dataset hacked poses far greater risks.

So there is again a need to align incentives. Ensuring that smart city technology procurement puts quality of security provided much more central in vendor selection is an issue that needs solving at a regulatory level. There needs to come a growing appreciation of the complexity of the interconnected web of devices. These are hard challenges to solve, but they cannot be ignored if smart cities are to thrive and be sustainable.

The smart city: a testbed for new economic models

A global economic transformation characterised by the proliferation of service industries that may replace even heavy industries and manufacturing is also reflected in smart cities.[2]

We are shifting from the current closed value chain towards an open value ecosystem. Energy production is undertaken by industrial and corporate energy vendors in a centralised manner, distributed to gas stations and then consumed in a rigid one-way transactional fashion. In the coming open value ecosystem, energy can be produced with solar panels, distributed on a transactive blockchain-based smart grid and consumed by the consumers (prosumers). Digitization turns our passive tools active. As infrastructure and energy trend towards commoditization, new economic value emerges from the production, collection, and analysis of data. This trend is reflected in all the other segments of smart cities.

Participants such as citizens, prosumers, software companies and local entrepreneurs who previously captured little to no value are now capturing more of that value. The success of this value-driven ecosystem depends on the premise that the right mechanisms are put in place to incentivise participants to share data and break current data silos.

[2] https://www.researchgate.net/publication/257334202_Smart_Cities_in_the_New_Service_Economy_Building_Platforms_for_Smart_Services

Electrification, autonomy, and access-over-ownership are reshaping every part of the industry and moving it into a new era of integrated mobility.

Dubai the Smart City

Dubai is the perfect example of a modern smart city. For a number of years now, Dubai has pursued an ambitious plan to use technology in an advanced but agnostic way transform the city into the happiest city on the planet, based around clear outcomes. The city is emerging as a real-world test-bed in which the Convergence Stack can be trialed. Smart Dubai is ready to embrace the potential of open and decentralised data to fuel innovation and economic growth. Here are 10 of the best examples.

1. The AI Lab. Smart Dubai has been working with partners across the city to implement AI wherever possible. Thirty-four AI use cases have now been identified, working with 13 government entities and spanning all city sectors. Rashid - the city's AI enablement layer - can answer questions related to any government query and is rapidly expanding its capabilities.

2. AI Principles & Ethics. Dubai's Ethical AI Toolkit has been created to provide practical help across a city ecosystem to ensure the benefits of AI are captured, but that the ethical considerations remain central to development. It supports business, government, academia, and individuals in understanding how AI systems can be used responsibly. The eventual goal is to reach widespread agreement and adoption of commonly-agreed policies to inform the ethical use of AI, not just in Dubai but around the world.

3. UAE Pass. The First National Digital Identity, UAE Pass provides a single mobile identity, giving residents and visitors of the UAE access to all local and federal government services, and an opportunity to authenticate and sign documents digitally.

4. Paperless Government. The Paperless Strategy is a concerted government-wide effort to leverage technology - blockchain, IoT, data and artificial intelligence - to remove paperwork from all government processes within the next three years.

5. Blockchain. Unlocking the power of blockchain to open the future economy from Dubai. A citywide Dubai Blockchain Strategy was launched with the objective of executing all applicable government transactions through blockchain by 2020. The strategy was designed around three pillars connecting government, the private sector, and the global community due to our strong belief in the power of collaboration.

6. Data as Fuel to Technology Development. All emerging technologies need to be fed with data to truly unleash their maximum potential. Smart Dubai has established a department dedicated solely to the effective management, governance and value-based exploitation of data across the city.

7. Dubai Private Sector Data Strategy. Smart Dubai has recently published a set of 12 policies, organised around four pillars - governance and regulation, commercialisation, engagement and people, and city technology and operations. Under each one, policies relating to decentralised exchanges will be found, but it is under the technology and operations that specific policy commitments to explore decentralised data exchange are to be found.

8. Dubai Pulse Open Data Portal. Dubai Data Establishment is working with over 350 data champions from Dubai government entities to identify and prepare data for ingestion into Dubai Pulse, the digital backbone of the city. So far, over 2,000 data sets have been identified and 270 data sets have been ingested into the Dubai Pulse platform.

9. Open and Shared Data Framework. Smart Dubai is providing opportunities in education and training to develop these technologies further. Smart Dubai is championing a number of skill development and enrichment activities for students and professionals, including the Consensys Academy for Blockchain, Rochester Institute of Technology for Smart City Development, Mohammed Bin Rashid School of Government for Data Compliance.

10. Smart Cities Global Network. The Smart Cities Global Network is the largest international network of smart city stakeholders. We aim to bring together partners that share our passion for advanced technology, Fourth Industrial Revolution breakthroughs, smart living, and spreading happiness in the community with tech-enabled, human-centric services. Network members include representatives from the government, the private sector, research centers, academic institutes, subject matter experts and the media.

Part 02

Building the Convergence Stack

The Convergence Stack is a further refinement of the Outlier Ventures investment thesis first published in 2016 anticipating the convergence of blockchains with IoT, AI and eventually robotics. Over the last three years, as the industry has matured, we have developed a more granular view of the specific technologies and protocols that make up Convergence. The Convergence Stack (Figure 1) is a representation of this emerging stack and sees data produced, distributed and consumed in an increasingly open, distributed, decentralised and automated way.

Covering hardware, software, networking and applications, the stack underpins a private, secure, and accessible digital infrastructure. We believe these technologies are vital in ensuring the benefits of technologies like the IoT and AI are shared equitably. The Convergence Stack is not just open-source and decentralised, critically it is coordinated by crypto-tokens. Crypto-tokens enable the coordination of economic activity. Not just between humans, but now we can include machines and agents, driving new levels of automation in the machine-to-machine (M2M) economy based on incentives rather than programming. This will likely become the greatest experiment in socio-economic experimentation we have ever seen, bringing about leaps forward not just in technology, but in economics and governance too.

In a smart city environment, we can expect to see experiments with how to govern in a more flexible, agile and inclusive way, empowering citizens to become active stakeholders and reduce the democratic deficit. We recommend using the Convergence Stack as a framework to strategically build a successful and happy smart city. The rest of the paper will explore a few technologies from the Convergence Stack that can be the first steps into making this a reality.

The View:

Younus Al Nasser
Assistant Director General
Smart Dubai

Outlier: What is the purpose of a smart city?

Our greatest aim is to have the happiest people in the world. Technology and data are very important means to this end. We want to use it to reduce the friction in city services and take the pain points out of life in the city, to create a great quality of life. This is why His Highness Sheikh Hamdan bin Mohammed al Maktoum has set the target for Dubai to be the first city government to fully adopt blockchain technology and for the city administration to be a paperless government by 2021.

Outlier: How are you planning to achieve your goals?

One of the initiatives we launched was the data initiative at the heart of the smart cities. We wanted a holistic framework that can address the exchange of this transformation between private, public and individuals as well as federal and local governments. The aim is to create the first emirate or city to enable the exchange of data across the city. To achieve this we needed a better and less centralised system than the ones we had in 2014 and 2015. So, we created a digital backbone that can support such an exchange with the purpose of bringing all parties to work and interact with each other. In the future, this exchange of information will scale to a national level to cater for artificial intelligence and blockchain use cases the country would like to implement. We want to transform the entire city, both public and private sector, and put the people at the heart of the transformation as individuals are the main constituents to serve.

The Convergence Stack

Application	6	Applications e.g. Balance.io, Veil, Graphite	Marketplaces e.g. Ocean Protocol, Streamer, Wibson	Learning e.g. Supervised, Unsupervised, Reinforcement
Interfacing	5	UX e.g. MetaMask, Brave, Status	API e.g. Infura, DAppNode, vipnode	Middleware e.g. Aragon, Augur, Dharma
Verification	4	Authentication e.g. Evernym, Handshake, WebID	Query e.g. The Graph, ChainLink, XYO Network	Compute e.g. TrueBit, Enigma, Starkware
Routing	3	Scaling e.g. Lighting, Plasma, bloXroute	Databases e.g. The Graph, Chainlink, XYO Network	Bridges e.g. ILP, Cosmos, Polkadot
Distribution	2	Ledgers e.g. Etherium, IOTA, Fetch.AI	Storage e.g. IPFS, Swarm, Sia	Networking e.g. libp2p, FB0SS, OpenFlow
Hardware	1	Processing e.g. HSMs, Intel SGX, AMD-SP	Storage e.g. Trezor, KeepKey, Ledger	Networking e.g. Gateway, Switch, Bridge

Decentralised Data Marketplaces

Data marketplaces are an emerging piece of the stack providing the necessary tools for trading, purchase and selling of data and digital assets. These marketplaces are made possible because of the technologies lower in the stack from hardware, distribution, routing, verification, and interfacing.

Without a free flow of data, there cannot be cross-collaboration between companies, residents, governmental bodies and entrepreneurs. Innovation cannot flourish and current data silos cause asymmetric advantages, fragmentation and work against the ecosystem-wide trust needed for innovation at scale. Many cities are already working on open data frameworks including Dubai, London, San Diego, and San Francisco. These are powerful initiatives, but they can be supercharged when combined with decentralised technologies. Making data exchanges decentralised unleashes a wave of permissionless services, and business model innovation that isn't possible when a single company or administration controls the exchange and network.

We will see the emergence of a whole host of new marketplaces beyond just today's cryptocurrency exchanges. Four specific types of new decentralised marketplace have already emerged: IoT data markets, AI data markets, personal data markets and digital assets marketplaces including crypto-assets, but also more exotic assets like non-fungible tokens (NFTs) and software bots.

Smart Dubai's Journey to build a Decentralised Data Marketplace

Building a decentralised data marketplace is the next significant milestone in Dubai's journey to become a truly data-driven smart city. We want to make this journey, guided by the Outlier Ventures Convergence Theory. Enabling and incentivizing direct data exchange between data holders will break data silos and bring improvement to people's lives, allowing individuals, private companies and public organizations to exchange and monetise their data in a sustainable and equitable ecosystem.

Smart Dubai's decentralised marketplace strategy includes the following domains. Activity under each of these will bring us to the point where by the end of 2019, we want to have established a working regulatory and technology sandbox.

Dubai Data Market Development
Four Principle Strategy Domains And Supporting Activities

TECHNOLOGY	COMMUNITY	MARKET	GOVERNANCE
Platform that uses blockchain technology to provide secure and immutable transactions. **Tokenization** to mask sensitive data elements. **Protocols** for peer to peer exchange of data.	**Use cases** that solve existing challenges and bring value to the city. **Partnerships** with public and private sector to seed the exchange with high-quality data.	**Incentives** for participants in the exchange. **Revenue model** that creates self-sustaining platform and allows data monetization. **Pricing mechanism** that gives fair value for listed data.	Favorable **regulations** that allows companies to experiment with innovative approaches. **Governance** to ensure appropriate data practices in usage, handling and sharing of data.

Alongside work under these domains, we will develop our thinking in a number of steps:

Publishing this paper
In this initial report we are setting out the route towards decentralisation, exploring various decentralised approaches.

Ecosystem workshop
A first formal engagement with the city data ecosystem, designed to expand our public and private sector network of 'decentralised actors', as well as to kick-start the important work of use case creation.

Building the first proof of concept
This will be the first version (MVP) of the decentralised marketplace. It will test and demonstrate the feasibility of the technology and expose any considerations to be addressed in future stages.

Decentralised hackathon
This significant and very public milestone will focus on building services on top of the marketplace and building a community of data scientists, developers and entreprene urs who will develop use cases that seed the decentralised exchange with high-quality data and showcase what is possible. At this step, security and features of the MVP will be tested.

Decentralised sandbox
This final step at the end of the year will establish a regulatory and technical sandbox, which allows for the sharing of monetised data using the marketplace around proven use cases. It will provide the platform for further growth of a fully operational city data market in 2020.

Artificial Intelligence Data Marketplaces

With the emergence of deep learning as a tool for a range of applications like facial recognition and natural language processing, we now have the potential to refine data to make digital oil. In most cases, data for AI algorithms tends to be accumulated by the largest companies. Decentralised AI data marketplaces can reduce, and eventually remove, the competitive advantage of hoarding private data by enabling anybody to contribute and use data. This will dramatically increase the number of contributors and users in a more equitable digital infrastructure.

For a city, artificial intelligence marketplaces can be a powerful tool. The single biggest challenge for all but a handful of Internet giants is the difficulty in accessing enough high-quality data to feed AI algorithms. This lack of access and ability to acquire the data, has already led to winner-take-all dynamics in a few technology areas like search, social media and e-commerce. As artificial intelligence follows software by 'eating the world', almost every product regardless of the market - healthcare, education, transportation, e-government services - will be infused with the powers of AI.

The challenge for cities is being able to foster a competitive environment for the delivery of services. Scenarios in which services are delivered by just a few market winners are sub-optimal. It is plurality and variety of supply that citizen needs and innovation potential will be balanced with business interests. A decentralised marketplace where data can be bought and sold and, with the right incentives, provided by crypto-tokens, can give service providers access to more data and at the same time enable citizens, organizations, and all sorts of bodies to monetise data. Smaller vehicle fleet operators, for example, can train their autonomous vehicles and level the field of competition with Waymo and Tesla.

Fetch.AI is solving the aforementioned problems by using machine learning and AI to enable people make use of their data. Digital entities, called Autonomous Economic Agents, can act independently on users' data to solve problems, transact and represent themselves, services, devices or individuals.

"It's all about convenience, that's why we give away our data. We are given a service and we are kind of somewhat okay with it. What if now I'm getting paid for the service I already like and getting paid for someone else to utilise data while I potentially might have even better control, visibility of who is using my data and for what purposes. If there's a large enough interest, that could drive the market."

– Ashley Pilipiszyn
AI, Blockchain & Energy Researcher, Stanford University

Project to Watch:

Fetch.AI

Fetch.AI have built the world's first smart ledger, allowing data to act autonomously. Using machine learning and AI technology, they enable data to cooperate, solving problems instantly and presenting answers directly to the user. It does this with Autonomous Economic Agents (AEAs) which are digital entities that can transact independently of human intervention and can represent themselves, devices, services or individuals. Agents can work alone or together to construct solutions to today's complex problems.

The digital world in which agents live is called the Open Economic Framework (OEF). Each agent sees a space-optimised in real-time just for them, where important things are clear and visible and less important things are simply removed. Underpinning the digital world is the smart ledger: a new generation of learning ledger that provides a collective super-intelligence to support agents' individual intelligences. It provides market intelligence, previously locked up in centralised silos, to everyone so that any agent that wants something is assured of the shortest possible route to find another that has it. Fetch's smart ledger scales to support millions of transactions per second and is able to restructure itself to present the OEF's digital world to the agents that use it.

FETCH

Personal Data Marketplaces

After peer-to-peer payments, control of personal data has been one of the most talked about applications for blockchains. This is related to but separate from self-sovereign identity, in the sense that once an individual controls their own identity, they can choose who can have access to it. This choice puts the individual in the position of the seller and the party who wants access to the data as the buyer.

Current data silos that gather data by providing "free" products have control over users' data, especially the ones that are saved in data centers outside the reach of the General Data Protection Regulation (GDPR). Users are unable to own, control or monetise their data which results in an unfair economic transaction. With personal data marketplaces, smart city goods and services providers are incentivised to follow best practices in regards to privacy, security similar or equal to GDPR. If they fail to do so as well as provide the best service, citizens could just opt out from sharing their data. This leads to a citizen-centric ecosystem which is the essence of a smart city. Residents can monetise data gathered from interacting with e-government services, their smart energy use or their lifestyle habits and profit while choosing who, how and when their data is sold.

Wibson has launched a blockchain-powered decentralised data marketplace that enables individuals to securely sell validated personal information in a trusted environment. Users can use Wibson's iOS and Android apps to connect to data sources such as their social media, mobile device location and other sources; they are then able to sell their data and get rewarded accordingly.

We will see the emergence of a whole host of new marketplaces beyond just today's cryptocurrency exchanges.

Project to Watch:

Sovrin

Sovrin is an open-source, open and global utility for trusted, self-sovereign identity. It is not owned by any single actor and anyone can use it and improve it. It enables any individual, organization or IoT to own and control their digital identity. They can verify the authenticity of claims and improve privacy by giving control of how, what and when information is shared. In a smart city, having one self-sovereign ID to access all services including federal and commercial, increases inclusion and improves user experience.

In the USA, for example, the credit unions have created a countrywide initiative called CULedger. The intention is for the credit unions take advantage of the Sovrin Network to give a new type of useful identity credential to their customers. This credential will be used every time a customer calls in, walks in or logs in to their credit union, bridging internal data silos. Additionally, the customer will have proof of name, address, and other KYC data from their credit union that they can use outside the credit union ecosystem at retailers and telcos.

sovrin

IoT Data Marketplaces

IoT data is already being captured and collected in vast quantities by sensors on infrastructure, vehicles, and user devices, but the sprawl of devices has created a fragmented ecosystem. On the consumer side, operating system providers like Apple, Google, and Amazon are attempting to leverage their dominant positions in smartphones and retail to sell increasing numbers of devices to collect more data.

As we saw, IoT devices can be owned by several parties in the smart city ecosystem that might not share the same incentives, goals and ambitions. Fragmented data collection from IoT devices in combination with misaligned business models results in poor collaboration, innovation and user experience for residents. IoT data marketplaces incentivize constituents including smart building owners, federal and local governments, autonomous vehicles fleet operators and citizens to share and exchange their data on those marketplaces. More entrepreneurs and companies can provide value which is driven by healthy competition and in turn, increases the overall value of the smart city.

Companies like Dawex are creating a data marketplace to offer a secure space for exchanging and monetizing all types of data captured by connected IoT devices. The data supplier configures the terms and conditions for monetization of data such as format, history, one-time-only transaction or a subscription. Legal and regulatory obligations necessary to handle transfers involving personal data are embedded in the marketplace.

> "The FAANGS don't need to share their data, but everyone else might need to in order to keep up. For automakers, they must respond to Tesla and Waymo, and one way is by pooling in a collective manner the autonomous driving data generated by their vehicles. They could pool their data using a decentralised data marketplace such as Ocean Protocol."
>
> – Ashley Lanquist
> Project Lead, Blockchain & DLT, World Economic Forum

The View:

Mark Nixon
Head of Smart Cities
IOTA

Outlier: Why do we need distributed ledgers to build better smart cities?

Over a year ago, I was conducting due diligence to build an aggregated data marketplace to connect telcos and IoT providers to the enterprise via a platform in a federated business model. I was looking into how best to facilitate data trade between data providers, IoT platforms with industry and government, and it became obvious that we needed something decentralised to scale rather than the traditional centralised data lake. People tend to build solutions in E2E silos, as they don't talk to each other, for instance, with urban planning. Urban planning has to do with the social aspect. What you effectively want is to remove closed silos and replace them with smart silos which are the key to open them all up, integrate and orchestrate. A solution to this is the Tangle because of its inherent properties.

Outlier: How do we fix business models, taxation and regulations?

The UK has a huge amount of tax coming from the big utility companies so it's extremely difficult to break into a smart energy sector, because you are restricted by the regulatory environment as the government is conscious of the tax it captures from large regulated, licensed providers. We should focus on how to adapt this new technology (DLTs) to provide new streams of taxes and income for local and central governments. Until we find a better tax system to avoid prohibiting growth while allowing for a fair amount of taxes, governments will be less likely to change regulation, if we can create new business models that take into consideration the overall taxonomy, we could create a new fairer, agile tax regime which will ultimately promote innovation that includes the government.

Project to Watch:

Ocean Protocol

The world has a data problem. The more we create, the more we are forced to entrust it all to data monopolies, who profit from it. Data is siloed, and generally hosted on proprietary databases across systems, geographies and business units. Ultimately, users are left with two options: give their data away for free (which is what most individuals do) or hoard it and see if they can make sense of it at some time in the future (which is what most companies do). Neither is very efficient or effective. There is no economic incentive to share data.

Ocean Protocol is a network for sharing data and services. It provides a tokenised service layer that exposes data, storage, compute and algorithms for consumption. It helps to unlock data, particularly for AI, and uses blockchain technology and tokenization so data can be shared and sold in a safe, secure and transparent manner.

Ocean is already in collaboration with the Singaporean government, working on a trusted data framework, data governance and technical services for approved sandboxes. This will help coordinate the relevant ministries and agencies to provide approved legal and regulatory framework for data sharing by industry and government.

ocean

Part 03

Conclusions

Unprecedented population and economic growth is turning megacities into state-cities, innovation hubs and economic powerhouses

As nation-states struggle to handle global challenges such as rapid climate change, energy crises, population displacements and political turmoil, cities are increasingly becoming well-equipped to fill this gap. People move into cities in droves, to make them dominant economic powerhouses, often with their own distinctive cultures and economic micro-climates. Characterised by growing populations, relative agility and flexibility in comparison to their larger counterparts, city government bodies can better adapt to exponentially growing technological and economic changes. Consequently, they can grasp the opportunity to lead the way for the Fourth Industrial Revolution, tackling as they go similar problems to nations, such as infrastructure, healthcare, mobility, broken business models and poor incentivization mechanisms for the participants.

Data is the key ingredient that drives data-driven business models and decisions, unlocking new economic value

Data is the core resource at the heart of smart cities. We only need to look at the big data factories such as Google, Facebook and Amazon to understand how much data is worth. It has granted these companies unprecedented network effects - the more data they control, the better their services are; the stronger the asymmetric advantage, the harder it is for new businesses to compete and deliver innovation. The free flow of data is necessary for open innovation, collaborative and fairer economic relationships. Distributed ledgers powered by strong cryptography and crypto-tokens can provide the foundations for a secure, transparent and peer-to-peer digital infrastructure of smart cities.

Decentralised data exchanges will unlock value from data. We now need to put a real value on it to drive a sustainable and equitable data ecosystem

The current open data frameworks led by city governments open up city data to everyone and invite participants to build solutions. But it is not enough. Open data initiatives can't change broken business models and broken incentives. We now need to put a meaningful value on data, to provide a way for it to be meaningfully priced and subsequently traded. This way we can create the incentives and profit opportunities to buy and sell data, and create marketplaces for all sorts of data - from sensor data to AI data. Decentralised querying and curation will also emerge

and algorithms and agents will spring up to trade on our behalf or for themselves. These advances in decentralised data exchanges will act as a counterbalance to the concentrated data control we have today to open up a whole new world of innovation.

The Convergence Stack: building successful and happy smart cities

For governments to stick solely with prevailing centralised digital infrastructures is to reject the chance to build better cities. Decentralised digital infrastructure is a strong alternative able to handle the convergence of technologies and markets that will make for frictionless city services and innovation in vital domains like mobility and climate management. And it can do so in ways that enhance security and privacy. The Convergence Stack will be a valuable guide as we build the next era of city infrastructure.

Cities like Dubai understand that for smart cities to thrive and be successful, they need to look beyond particular technologies or market initiatives. They must take a holistic and integrated view and work with the market so that emerging opportunities can be grasped. They need to see that the IoT, blockchain technology, and artificial intelligence are all interconnected and converging to form a decentralised production, distribution and consumption data ecosystem.

Only once the production, distribution, and consumption of data have been decentralised can the benefits of a smart city be shared widely and equitably. Outlier Ventures is embarking on a journey with Smart Dubai to make a reality of the world's first Convergence Stack in one of the world's smartest cities.

As we embark on the broader journey to build the digital infrastructure for the Fourth Industrial Revolution, the Convergence Stack provides cities around the world with the framework to make sure they aren't just smart, but they are successful.

Conclusion:
Data is the key ingredient that drives data-driven business models and decisions, unlocking new economic value

Data is the core resource at the heart of smart cities.

Appendix

Interviewees

1. Ashley Lannquist
Project Lead, Blockchain & DLT,
World Economic Forum

2. Harry Kalliaras
Advisor to the Mayor, City of Trikala

3. Younus Al Nasser
Assistant Director General,
Smart Dubai & CEO of Dubai
Data Establishment

4. Andrew Collinge
Advisor, Smart Dubai

5. Dietrich Sümmermann
CEO, MotionWerk GmbH
& Share&Charge

6. Shyam Duraiswami
Cognitive Manufacturing &
Connected Vehicles Architect, IBM

7. Patrick Luk
Professor and Chair in Electrical
Engineering, Cranfield University

8. Dan Hayes
Founder, VRCO

9. Ashley Pilipiszyn
AI, Blockchain & Energy Researcher,
Stanford University

10. Alexander Renz
Managing Partner,
New Mobility Consulting

11. Nitin Gavhane
Lead Architect,
Energy Web Foundation

12. Kyle Solomon
CEO, Adosia

13. Ana Trbovich
Co-founder, Grid Singularity & Energy
Web Foundation

14. Richard Brown
Founder, Autoexchange

15. Sohail Munir
Emerging Technologies,
Smart Cities Innovation and Digital
Government Transformation,
Smart Dubai

16. Bert Brans
VP Business Development EMEA,
Sentiance

17. Jarkko Jaakkola
Area Manager, MaaS Global

18. Zeina El Kaissi
Head of Emerging Technology
Smart Dubai

19. Sandra Särav
Global Affairs Director,
Estonian Government CIO Office

20. Rachel Smith
Transport Planner,
Bus+Active Technical Specialist,
Congestion Reduction

21. Mayank Malik
Chief Architect, SLAC National
Accelerator Laboratory,
Stanford University

22. Wayne Tian
Oversea Operations Director,
CPCHAIN

23. Irene Wei
Oversea Operation Manager,
CPCHAIN

24. Stina Brock
SVP North America, Electron

25. Toon Vanparys
CEO, Sentiance

26. Nathaniel Kolbe
Director, Superfusionlab

27. Mark Nixon
Head of Smart Cities, IOTA

28. George Koutitas
CEO, Gridmates

29. Gosbert Chagula
Co-lead, Escape the City

30. Evangelos Pappas
CEO, Ocyan

Engage with us

Our reputation has originated as a consequence of our deep commitment to open research and thought leadership in the decentralisation space broadly, and more specifically, through our Convergence Stack thesis.

We engage regularly with start-ups, academia, and the corporate ecosystem and are open to collaboration and consulting opportunities throughout the community. Current research themes are focused on smart cities, energy, mobility, connectivity, augmented reality, and "crossing the chasm" to mainstream decentralised technology adoption.

If you wish to discuss your project or initiative further, please contact Lawrence, Charlotte or Catherine. If you wish to discuss Smart Dubai's approach to exploring decentralised approaches, please contact Andrew.

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