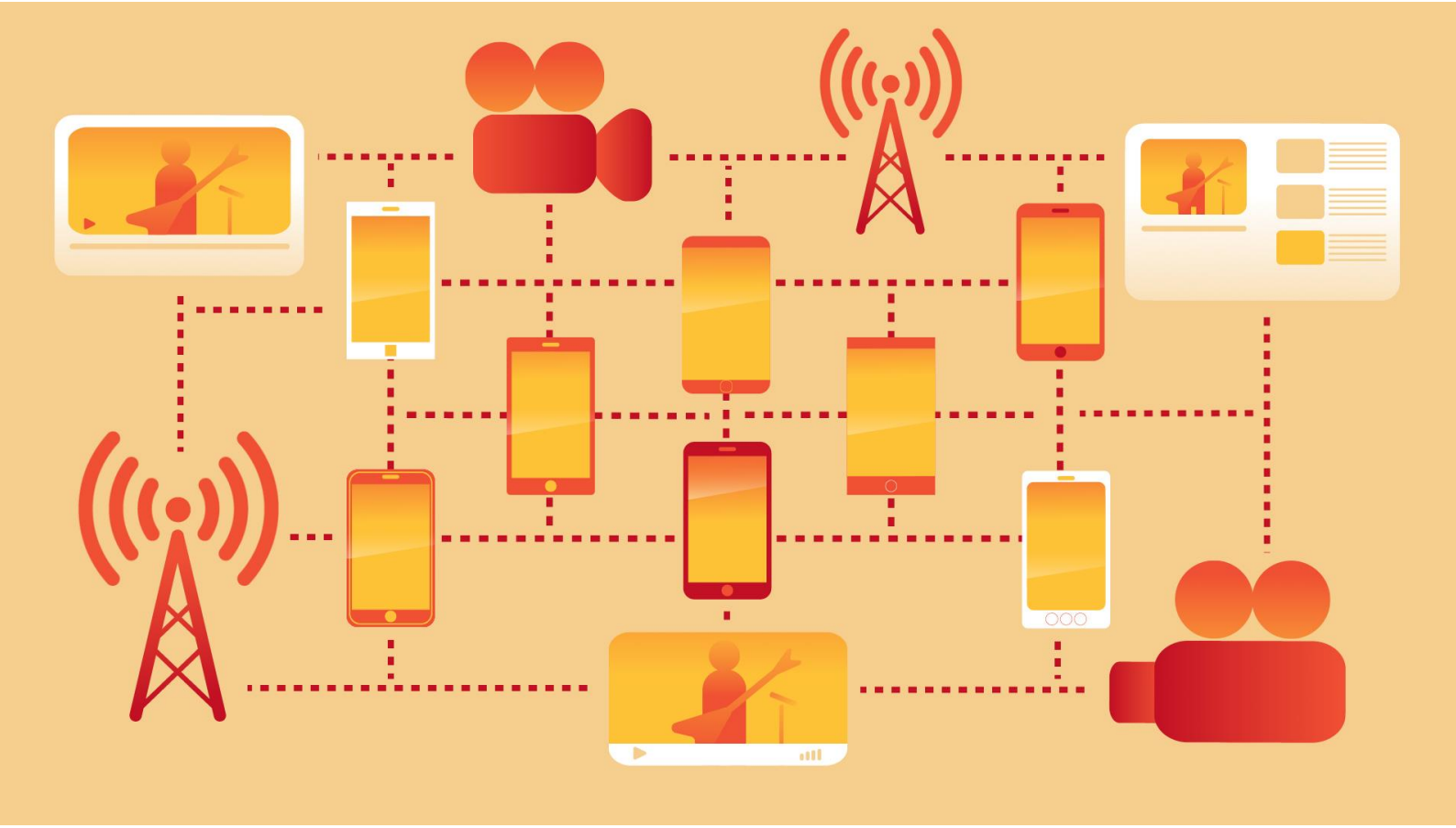

Urban Media Experiences powered by FLAME

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EXECUTIVE SUMMARY

Today, users want more engaging and meaningful media experiences, especially localized to their context and community. Physical and virtual spaces are colliding, allowing mobile users to move between increasingly interactive and content-rich spaces, and to participate in co-creation of experiences that bring together digital and physical worlds. User demands and technology trends are pushing media companies to search for new technologies that engage with users, communities and spaces to create places for culture, entertainment and learning.

FLAME is building a software-based 5G platform for the deployment of Future Media Internet (FMI) services across the city. 5G technologies and new network paradigms fulfil the strict requirements of the new trends of media services in terms of low latency, flexibility, high fidelity, etc. This whitepaper identifies these market trends and pays special attention to the offering of localised experiences in the city. This is one of the relevant media and entertainment use cases for 5G. The city is not only a place to live or to consume media content. The city is also a place to enjoy cultural experiences that involve media, to interact with other people, to learn about symbolic values (like the city's history) or to play games. In fact, one of the main city trends is the generation of content by users, who immediately share it via social networks.

As described in this whitepaper, the project has deployed the FLAME platform on real smart city infrastructures to enable new media validation experiments. These experiments have confirmed the FLAME technical proposition for media services and have revealed insights into the way users interact with the city.

FLAME has also produced whitepapers to explore the intersections between 5G and Future Media Internet (FMI) [1] and to identify common patterns that can benefit from the FLAME technical approach [2].

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1 FLAME BENEFITS AND MEDIA INDUSTRY MEET IN THE CITY

The current media panorama is characterised by the creation and deployment of **new media services** jointly with new user habits and consumption patterns. Some of the most significant **new services and media trends,** as described in [3], are:

- Demand for **improved quality**, including **more pixels** (e.g. beyond 4K resolution) and also **better pixels** (e.g., HDR or WCG). This category integrates characteristics like dynamic range, resolution. frame rate, spatial audio and video colour gamut. This trend is consistent with the new capabilities of cameras and acquisition equipment (able to provide high quality media material) and with the features of consumer electronics (according to the manufacturing industry strategy). This signal improvement impacts directly in the throughput required for transmission.

- New technologies that provide **an enriched user experience**, beyond the unidirectional presentation of video and audio. **Gaming, AR, VR and MR** are good examples of this trend. Users look for **more engaging, immersive and exciting experiences**. **360-degree media**, which is often considered VR even if it presents real acquired video, is another example of improved experience, trying to wrap the user perception (i.e., the immersion).

- **Localised contents and experiences**, linked to a physical or symbolic space, like a sports match or a cultural festival in the city, in order to achieve better enjoyment.

- Many **content consumers become content producers**. Modern mobile equipment enables quality media acquisition and social networks enable the transmission in real time. This phenomenon is also connected to the localised experiences described in the previous bullet: many users desire to disseminate their participation in public events. Social networks enable this desire instantaneously.

- Users wish to watch **any content anywhere and at any time**, e.g., when they move across the city or they commute.

The FLAME platform is a solution for the deployment of these new media services in the smart city. FLAME enables the **orchestration and management of media services, optimising the use of both cloud and network resources** provided by a distributed and virtualised infrastructure. FLAME offers the provision of media services as service function chains, as a concatenation of virtualised elements [3].

Looking at the service dimension and the network evolution in the FLAME context, we can state that **5G** will not only introduce a new generation of mobile broadband networks with improved capabilities, like more bandwidth, reduced latency and higher reliability, but it will also enable **a unique 'service capability**' [3].

As stated in FLAME deliverable D2.4 [3], "The initial phase of 5G deployments focuses on eMBB (enhanced Mobile Broadband) service type, which provides greater data-bandwidth together with an improved latency. Thus, the first emerging use cases are AR/VR/MR media applications, localised content producers, UltraHD or 360-degree streaming video, etc. While 5G sounds exciting and is being launched with its ability to be a game-changing technology, the truth is that firstly strong business cases need to be demonstrated so that communication service providers (CSP) get a return on their huge investments (in spectrum auctions, new infrastructure (towers, antennas, equipment, miniDC at the network edge), transformation of the software network operations, etc). There is an unprecedented pressure on revenues and tension with the Over-The-Tops (OTTs) that are winning the

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service consumption model (e.g. Netflix, Amazon Prime, etc). OTT refers to delivery of audio, video and other media contents over the internet".

The key is not to spend more money on network infrastructure, but it is also about deciding where future revenue is going to come from, by evaluating where CSPs have value to add, for example in digitalization of enterprises business or **offering new media services for massive B2C E2E scenarios from edge to core datacentre (DC) deployments**. Optimised new services making the most of network edge and computing capabilities is the next battle and FLAME platform offers a multi-layer control across and an optimised routing solution [3].

In addition, the FLAME platform specifies an **easy description of the network service** as service function chains (SFC), offering the programmability, deployment and management of media services, enabling a service DevOps process for faster new media service creation and deployment. The average '*service creation time*' is one of the main KPIs defined by the European 5G PPP initiative targeting a reduction '*from 90 hours to 90 minutes'* and FLAME project is contributing to it [3].

FLAME capabilities optimise the performance of media services, including an innovative routing solution. The overall FLAME benefits for service deployment are: low latency compute and delivery (key to new interactive media services at the far edge of the network), fast and dynamic service request routing (key to personalised and mobile services), multicast delivery of HTTP responses (key to scalability), network-level indirection (key to replication of content based on local relevance), and more secure content objects (key to content replication while preserving content security and end user privacy).

FLAME validation scenarios and third party experiments are excellent examples of how these platform capabilities are impacting the creation and deployment of new media services, as explained in section two of this whitepaper. FLAME validation scenarios and third party experiments present most of the characteristics and trends of media services. Moreover, FLAME validation partners have identified additional use cases to be offered in the facilities, utilising FMS (or Foundation Media Services, developed in FLAME) components to build more complex media services.

FLAME has produced a specific whitepaper [1] to explore the intersections between 5G and Future Media Internet (FMI) from the FLAME contribution perspective, to outline the drivers shared by 5G and FLAME and the main contributions of FLAME to 5G developments.

These capabilities of the FLAME platform to support new services and the set of FLAME benefits cannot be seen without considering the close relationship between FLAME and 5G deployments in the city facilities. FLAME is deploying similar technological paradigms that are necessary for 5G to ensure a massive deployment, such as software network virtualisation (NFV/SDN) and automated service deployments as virtualised components that make the most of the edge network too (MEC scenarios). On the other hand, the new services deployed by the validation scenario partners satisfy the six use cases that the 5G-PPP has identified for the media industry [4]. In this way, the future 5G network with its slicing capabilities to fulfil media scenario requirements is a key point for enabling new services in FLAME. [3]

The existence of deployments in realistic smart city facilities is essential in order to test new services, to extract measures and conclusions about the new service performance supported by FLAME's benefits and to understand their impact. The extraction of measures and the generation of knowledge about the performance of the new services are key outcomes of the project. These service metrics and their link with QoE and QoS parameters are especially profitable for media service providers. Media service providers, which are responsible for the design and deployment of new services, find crucial capabilities in FLAME: a platform for the orchestration of media services; advanced foundation media

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services (FMS) to re-use; real-life city infrastructures for testing and validation; and suitable measurement and knowledge about their service performance. [3]

Media service providers are not simple OTT operators on FLAME-enabled facilities: due to the multilayer FLAME approach, the media provider not only uses the underlying network capabilities, but the network is adaptive itself to optimise the new services quality, according to the policies established by the media service provider. [3]

But the city is not only the place where media services are distributed and consumed. The city is a place for experimentation, participation and interaction, which stimulates contact among citizens and which links citizens with urban symbolic values, like the city's history.

The public space even stimulates a sort of city gamification. Citizens repurpose their surroundings for playful behaviour: squares become the stage for a flash-mob, obstacles become a challenge for Parkour runners, and lines on the pavement become traps we should not step on. This kind of city-gamification can be partially shifted into the virtual world – especially within a smart city, where computational resources are readily available and data exchange between users is faster than ever. Augmented Reality (AR) technologies enable mobile devices to recognize city features, overlay them with fantastic 3D models, and allow virtual interactions with those objects. Therefore, AR is a key technology to repurpose parts of the real world into an environment of play. Smart city infrastructure can be used in a variety of ways: sensors, for example, can give input to the virtual representation and local servers synchronize the state of the virtual augmentation for several players, such that all of them can see the changes other people apply to the virtual world in real-time. A key factor for these capabilities is speed. Not only from the mobile devices but also the server infrastructure. Synchronization for several players must be instantaneous to give the impression of the augmentation being real.

FLAME ensures these capabilities through employing 5G standards, low latencies and low hop count. Game Developers are given the ability to write policies that start game servers next to where the game is situated and scale-up the servers' resources depending on how many players are expected to participate. Having a dedicated server to distribute and mitigate changes by different users is a definite requirement for city-wide gaming. The closer the server is to the players, the lower the latency and the more specialized it can act upon the users' behaviours.

Using the city at the level of a virtual game adds an additional high-level mechanic to the game, as players have to navigate the area. The concept of moving in a city as a game mechanic has only been adapted by few pervasive games, such as Pokémon GO, Ingress or 'Can you see me now?'. It requires developers of urban games to consider walking distances in the real world and reason about how these integrate into the virtual game mechanics. For example, the walking and running durations between the interactive spots have to be taken in account when balancing the game.

Thanks to the FMSs provided by the FLAME platform, placing a database server near the player becomes a straightforward task. The availability of local databases allows client game applications to be kept small, as the 3D content can be loaded from a nearby database as soon as it is needed and later to be discarded again. Due to these local databases, it is also possible to give the game a completely different look depending on where in the city / world the player is. Especially for AR games, which project their 3D content into the real world, this can lead to very interesting applications. Imagine a database residing in the old town which delivers 3D models with a more dated look to better fit into the environment, whereas databases residing in the banking sector would return more modern looking assets. Both assets have the same functionality and are requested over the same identifier, such that the app can be agnostic to its actual real-world location.

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2 VALIDATION SCENARIOS AND THIRD PARTY TRIALS

PARTICIPATORY MEDIA FOR INTERACTIVE RADIO COMMUNITIES BY VRT

VRT Innovation, a FLAME partner, has developed two qualitative user experiments to explore the innovative technical capabilities and the value of the FLAME platform for developing new media interactions inside the city. In a third 'Urban Hacking in 5G' hackathon activity, VRT presented the design and outcomes of these experiments as examples of how a public broadcasting company searches for new interactive and participative media experiences. In the FLAME project, VRT explores how it can improve the engagement of city communities in producing media together.

In the first user experiment, on Mobile Journalism, participants were asked to join a role-play of a fictive local media company. The role-play aimed to evoke a context where participants experience the challenge of capturing compelling news stories and where they can experience newsroom time pressure. The teams were asked to create two short news bulletins capturing citizens' thoughts on the current and the future city. All participants got an introduction course on mobile journalism and storytelling. The newsroom editors guided the remote journalists using a live chat channel, provided via a mobile application developed by VRT. Captured videos were sent to the newsroom using the FLAME platform.

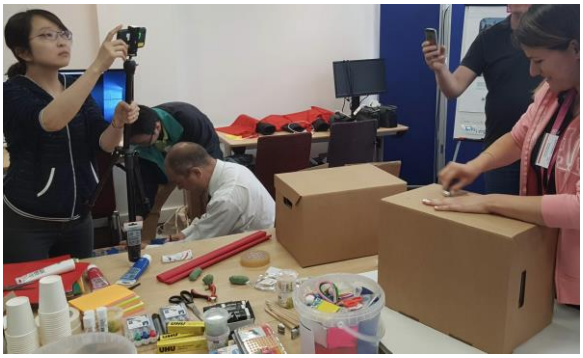

Figure 1. The journalist as a designer. Creating tangible conversation-openers used in interviews (Photo FLAME , 2018).

Figure 2. Local news room activities. Incomming interview (Photo Marc Godon, VRT Innovation, 2018).

In the second experiment, VRT deployed an interactive media application on Millennium Square, in Bristol, stimulating a debate on future city challenges. The FLAME platform was tested on its capabilities of media distribution involving media encoding, storage, and load balancing at the edge of the network. Participants were asked to respond with their own videos on several sustainability challenges posted at a particular spot on the Millennium Square. Access to media was limited to the immediate surroundings of the square; suggesting a physical experienceable media interaction zone. After this outdoor experiment, participants were asked to envision their own desired media interaction system in a workshop.

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Figure 3. Students explore the interactive media trail with Bristol's Sustainable Future plans and the UN SDGs as themes [6] [7] [8] (Photo Marc Godon, VRT Innovation, 2019).

Figure 4. Participants explain their vision of the city's future and the role of new interactive media to Smart City experts (Photo Marc Godon, VRT Innovation, 2019).

The first experiment, on Mobile Journalism, revealed the potential value of media creation and collaboration tools. Tools proactively resided in the FLAME edge network, to assist the lightly equipped journalist in their fast-responsive creative work. One team did experiments with 360-degree media and virtual reality technologies to illustrate the potential value of, e.g., remote directing. Participants agreed on the importance and excitement of collaborative storytelling in the City and the positive influence of the high quality of service networks on distributed and collaborative media production workflows enabled by the FLAME platform. The first experiment confirmed the valuable idea of a virtual editor room, together with smart tools to support the creative act of making media, deployed in the edge of the FLAME network.

The second experiment, on Millennium Square, demonstrated the value of deploying an interactive media experience in a public place. Using this square as a mise-en-scene worked very well. According to a historian: this should not be surprising. Public places, such as Millennium Square, have always been the ultimate meeting place for commerce or entertainment. They enable citizens to meet each other or visitors and exchange stories. In the experiment, we link a digital social network with a physical city space – in a meaningful way. It fits, and it adds value. A close integration can be done using the different service components deployed on the FLAME platform. Public broadcasters should explore further this potential symbiosis between local media creation and city life.

One aspect, common to all experiments is the observation of the ease of imagination, the fluent incorporation of design thinking and media creation techniques, and the civic-mindset of the proposed applications leading to the sharing of a better understanding of their city. This could confirm the existence of a positive interference between two systems. 'The City', continuous in transition with its need for innovations, and the FLAME platform which is supporting the easy creation of local interactive media experiences.

PERSONALIZED MEDIA MOBILITY BY NEXTWORKS

Entertainment systems are getting increasingly popular in homes and public spaces with applications for media distribution over various fixed and personal/portable devices pervading our daily lives. Many broadcasters have developed multichannel television offers (e.g. Sky Go, DISH Anywhere, Netflix, NowTV, etc.) mixing together fixed interactive digital platforms (e.g. at home) with complementary streaming applications, run on mobile devices for the fruition of movies, entertainment and sports events while on the go. When it comes to personal media fruition (e.g. access to personal digital

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content in home-based Video-on-Demand platforms or video-surveillance recording systems) opportunities for accessing personal media everywhere becomes more limited and usually it does not extend beyond the personal home network.

The PERSONALIZED MEDIA MOBILITY (PMM) scenario developed by Nextworks for the FLAME infrastructure in Barcelona aims to cover this space and focus on the Personalisation, Interaction, Mobility and Localisation (PIML) aspects of the media distribution in the Smart City. In particular, we have built an experiment to evaluate how media service providers can serve users on the go within the Smart City taking benefit of some key FLAME platform services like:

- Intelligent service endpoint management
- Dynamic service routing to direct traffic to the most appropriate local service instance
- Reduction of network traffic through localizing traffic wherever possible, also addressing the aforementioned latency reduction.

Figure 5. PMM scenario representation

The PMM experience we are building aims to implement a service of 'my screen follows me', from home to my smart hand-held devices in order to continue media consumption while walking in the Smart City. The main concept is that a user swipes media from a fixed video/audio device at home to personal mobile devices (e.g. tablets, smartphones) and moves within the FLAME urban area. The FLAME platform automatically instantiates content caches and adapts routing in media service chains to guarantee the best streaming experience while on the move.

With our PMM experiment we aim to validate how FLAME can go beyond the traditional content delivery network (CDN) architectures currently available for media distribution over IP, and test a PMM service over the FLAME platform to evaluate which surrogate functions for media distribution can be better used to serve various endpoints in the FLAME-empowered Smart City.

Our experiment is developed along two main scenarios. In **Scenario 1: PMM distribution in walking areas in Barcelona,** our goal is to validate how my screen and preferences follow me from home to my smart hand-held devices to continue media consumption while walking in the Smart City. In **Scenario 2: PMM on aggregation areas of the Smart City,** the 'my media follow me' service extends also to aggregation areas (e.g. shop, cafeteria, and mall), and surrogate functions for media distribution are allocated in edge nodes for more users.

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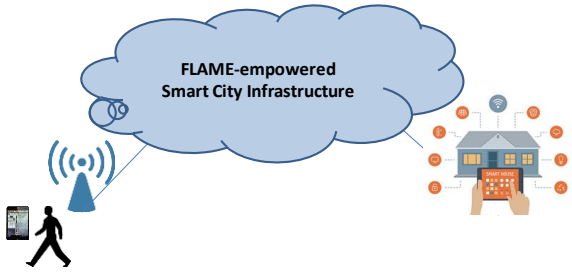

Figure 6. PMM Scenario 1 - Distribution of personal media in walking areas in Barcelona

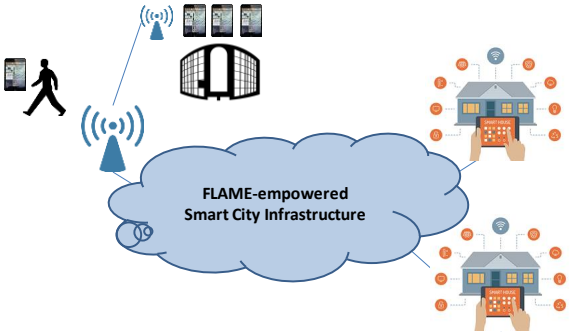

Figure 7. PMM Scenario 2 - Distribution of personal media in aggregation areas of the Smart City

In terms of experiment components, a Personalised Media Origin Server, representing the home-based media streaming platform (based on Symphony by Nextworks), which is deployed at the core data centre of the FLAME infrastructure in the FLAME data centre facility in Barcelona. The Media Origin Server is connected through the FLAME platform (using the FLIPS routing) to street cabinets for FLAME edge computing in the area of Pere IV district in Barcelona, where end users can connect to the FLAME infrastructure via Wi-Fi and where FLIPS routing implements the more QoS convenient routing to local cache instantiated at the various edge points.

As users move across the experiment field, the PMM application orchestrator and FLAME platform automatically activate replicas of Media-Service-Function at different towers, based on measured QoS performances (e.g. latency), thus optimizing the experienced streaming performances.

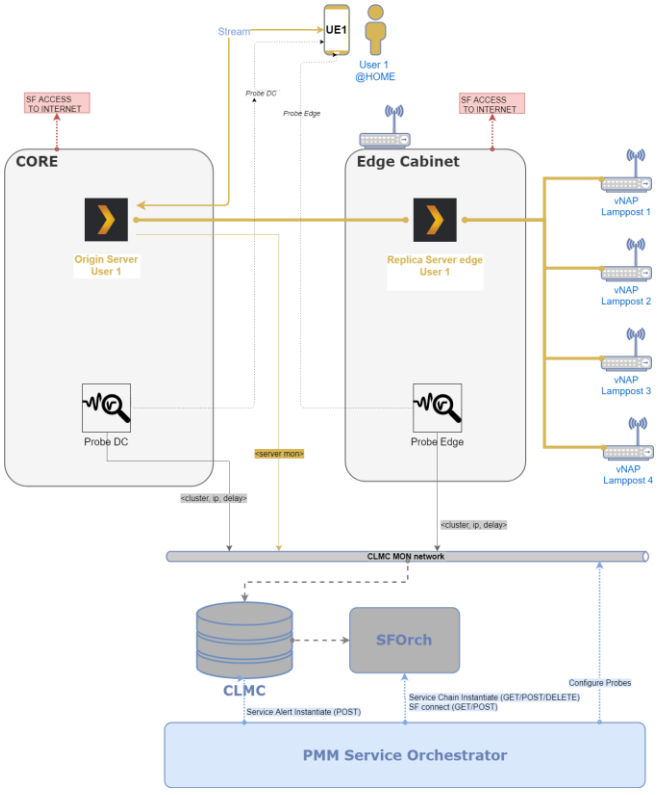

Figure 8. Logical schema of PMM experiment in Barcelona

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Figure 9. Application monitoring data in FLAME Cross-Layer Monitoring Controller for automatic service scaling

GNOME TRADER BY ETH GAME TECHNOLOGY CENTER

Mobile gaming has been on the rise for several years. Smartphone games are getting increasingly sophisticated: not only from a gameplay perspective but also in terms of visual quality. But the visual beauty comes, among other factors, at the cost of higher data storage requirements: hundreds of high-resolution textures and 3D models have to be stored on the device. This problem can be mitigated by streaming assets to the mobile device when they are required and persisting them in volatile memory. With the increased bandwidth of 5G, such scenarios are no longer a mere vision.

The Game Technology Center at ETH Zurich, Switzerland, has been developing a team-based urban arena AR game called *Gnome Trader* which downloads certain 3D assets only once they are required. The goal of the game is to collect as many tree seeds as possible for your team. Seeds can be gained by planting virtual trees in the AR garden or by trading seeds with one of four AR shops distributed equidistantly within the urban arena. Visiting a shop can only be done by walking to its specific location in the arena and scanning the AR marker located there. The prices of the shops are calculated by a supply and demand simulation. Therefore, prices can be different in various locations of the arena, giving the players an incentive to visit different shops over time.

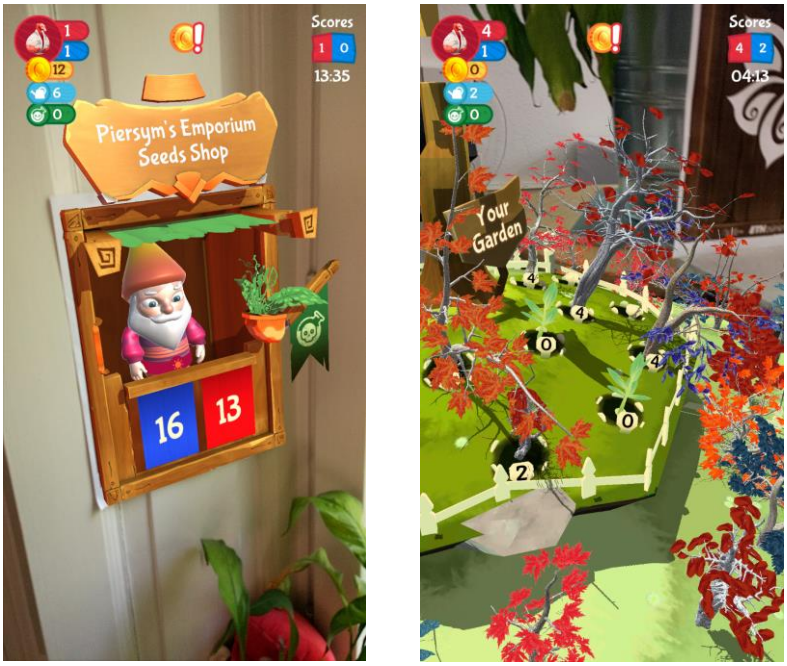

Figure 10. The AR interactions happen on the virtual shop (left) and the virtual garden (right).

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Figure 11. The red team is planting seeds in their garden.

Every planted seed eventually grows into an unique looking tree. The 3D models for these trees are not stored in the app, but on nearby servers. Therefore, as soon as a tree model is required, the application will download it from a nearby server. The servers used for this are instances of the storage FMS provided by the FLAME platform. One storage FMS is pre-loaded with the 3D assets, whereas a second storage FMS is pre-loaded with lower quality versions of the same assets. Since FLAME allows monitoring average round trip times (RTT) of requests, a policy is employed that switches between the two databases depending on how congested the network is. When the RTTs are becoming too long to assure a seamless gaming experience, the lower quality storage FMS is activated. The smaller file sizes of the assets leads to shorter download times and therefore reduces the load on the network. Consequently, more players can be served simultaneously.

The network load is further reduced by the use of multicasting: all players are notified simultaneously when a new asset needs to be downloaded. Therefore, the different devices will request that asset at roughly the same time, which results in multicasting over the network. This means that the database has to fetch the newly required asset only once and the FLAME network will take care of broadcasting the item to all simultaneous requesters.

During a playtesting of this city-wide game, players picked up quickly on how to interact with the AR components. Also, the participants soon started running back and forth between the garden and the shops in order to make good deals, while still managing their gardens. The combination of virtual world and urban environment worked well in this case.

LOCATION-BASED AR STORYTELLING BY DRZ

The FLAME platform also supports the delivery of multimedia content for location-based augmented reality (AR) stories. Such stories can be used for applications including entertainment, education or tourism. By augmenting the physical world with digital content, a new level of immersion is reached and could, for example, bring historic scenes back to life in front of the user's eyes. These applications benefit from new and advanced media services that are localized within the physical environment. The FLAME platform enables intelligent orchestration and management of these media services.

The location-based AR storytelling system presents multimedia content as part of the storytelling process. Some of the story content is video, audio or text, and a special emphasis is placed on delivering virtual 3D renderings of animated characters and props in mixed reality environments. A primary design concept is to not require the mobile application to have all content to be preloaded. Instead, a lightweight mobile application is capable of downloading content that is contextually appropriate based on both the physical location and the state of narrative progression of the user.

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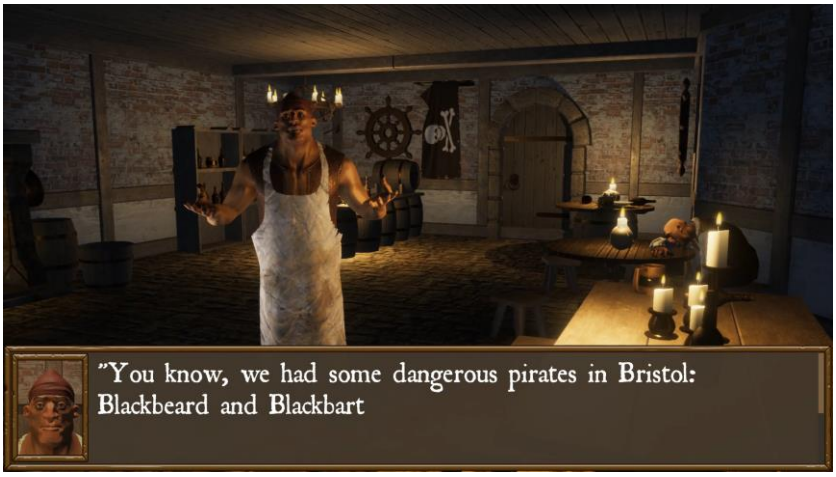

Figure 12 The pirate inn stage where innkeeper Pius informs the player about two famous pirates of Bristol, Blackbeard and Blackbart.

The location-based AR storytelling concept has been demonstrated using the FLAME platform hosted at Millennium Square in Bristol, UK. The story is a treasure hunt that also helps the player learn about Bristol's rich history in sea-based exploration and trade (e.g. see Figure 12). The story is acted out on different AR stages. These AR stages are mapped to specific locations on the Millennium Square with the help of GPS and AR technologies. When the user is in the GPS proximity of one of these locations, the corresponding stage is downloaded. The stage is then visualized as soon as the associated AR marker is found. The AR markers are used to properly orient the stage relative to the real environment, which brings together the digital and physical world. Figure 13 presents two of the AR stages.

Figure 13 The alley stage (left) includes a treasure map that must be collected. The treasure stage (right) allows for digging up the treasure only after the map has been translated.

The FLAME network allows for spatially distributed multimedia content within a city, such that it is available near the location where it will be consumed. For a media service provider, this enables localized control of latency and bandwidth to reduce retrieval time. For the media consumer, the content does not have to be pre-downloaded onto the device, but can be streamed gradually as the story unfolds.

The FLAME platform also offers intelligent resource management capabilities. For example, when users simultaneously request the same multimedia content, it is efficiently delivered using advanced multicasting technologies. Another example is that the FLAME platform provides interfaces to automatically orchestrate the lifecycle state of localized media services. For the location-based AR storytelling scenario, media services are only actively running when a consumer is in the physical proximity of the service, resulting in more efficient resource utilization.

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THIRD PARTY MEDIA SERVICE TRIALS BY UNIVERSITY OF SOUTHAMPTON IT INNOVATION CENTRE

FLAME has conducted 15 trials with European companies from the creative industries and beyond, with further experiments planned for 2020. Each company has used FLAME to enhance localised service offerings to consumers in broadcast, gaming, social networking, tourism, sport and transport. The companies were selected through a competitive open call to select proposals offering the most exciting and innovative ways to deliver media within urban settings. The variety of experiences include: interactive augmented reality guides and social networking; live crowd-sourced, personalised and inter-vehicle video streaming; high-throughput live streaming of 4K 360-degree virtual reality for inclusion at public events.

Figure 14: Live streaming in vehicle area network

The diversity of experiences demonstrates the general applicability of the FLAME platform for delivery of advanced media services. To capture the knowledge from trials and allow other companies to follow, FLAME has derived a set of media service design patterns by analysing content flows and feature usage by the trials. The patterns describe common interactions between consumers and services that are enhanced by FLAME features such as service routing, multicast and geographical scaling. The patterns allow developers to architect systems through flexible micro-services that are programmatically controlled and managed through FLAME policies. The use of patterns accelerates understanding of how FLAME can be used to enhanced media services. This has significantly increased in the use of advanced service management features and foundation media services.

FLAME's media services trials with third parties have been extremely important for assessing the performance, viability and acceptance of the FLAME platform, as well as the accelerated DevOps pipeline underpinning experimentation, service development, integration, testing, deployment and evaluation. The FLAME ecosystem is now supporting more than 20 companies bringing together more than 40 developers and more than 100 users to co-create experiences whilst learning and realising the benefits of 5G service delivery and mobile edge computing. The scale of activity can only be achieved through automation within the experimentation and trials process. Feedback from third parties on the FLAME offering has been good in terms of learning and opportunities for commercialisation.

"We are most certain that thanks to the smart and targeted support of the open call, the [ARENA] platform can be released in 2020." Millform Inc, 2019

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[8] With support from Frederik Bordon, EU-Benelux Communication and Special Events, United Nations Regional Information Centre (UNRIC), Informing and Engaging Europeans. See also: https://www.unric.org, https://go-goals.org, https://sdgactioncampaign.org, https://unfccc.int, https://www.youtube.com/user/climateconference, http://worldslargestlesson.globalgoals.org.

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