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### USER APPLICATION DELIVERY OVER AD-HOC WIRELESS COMMUNICATION NETWORKS

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#### Abstract

A communication system receives a network identifier for a communication network from a user apparatus. The communication system receives an application identifier for a user application that uses the communication network from the user apparatus. The communication system receives an application username that identifies a user of the user application from the user apparatus. The communication system receives a request that indicates the network identifier from another user apparatus, and in response, transfers the application identifier and the application username to the other user apparatus.

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## Background/Summary

RELATED CASES [0001] This United States Patent Application is a continuation of U.S. patent application Ser. No. 17/875,200 that was filed on Jul. 27, 2022 and is entitled “USER APPLICATION DELIVERY OVER AD-HOC WIRELESS COMMUNICATION NETWORKS.” U.S. patent application Ser. No. 17/875,200 is hereby incorporated by reference into this United States Patent Application.

### TECHNICAL BACKGROUND

[0002] Wireless communication networks provide wireless data services to wireless user devices. Exemplary wireless data services include user data messaging, machine-control, internet-access, media-streaming, and social-networking. Exemplary wireless user devices comprise phones, computers, vehicles, robots, and sensors. The wireless user devices execute user applications that use the wireless data services. For example, a smartphone may execute a social-networking application that communicates with a content server over a wireless communication network.

[0003] The wireless communication networks have wireless access nodes which exchange wireless signals with the wireless user devices over radio frequency bands. The wireless signals use wireless network protocols like Fifth Generation New Radio (5G NR), Long Term Evolution (LTE), Institute of Electrical and Electronic Engineers (IEEE) 802.11 (WIFI), and Low-Power Wide Area Network (LP-WAN). The wireless access nodes exchange network signaling and user data with network elements that are often clustered together into wireless network cores. The wireless network elements comprise Access and Mobility Management Functions (AMFs), Session Management Functions (SMFs), User Plane Functions (UPFs), and the like.

[0004] The wireless user devices may directly communicate over point-to-point wireless links. The wireless user devices may form ad-hoc wireless networks that are comprised of these point-to-point wireless links. The ad-hoc wireless networks use wireless protocols like Direct Short Range Radio Communication (DSRC), 5G NR, WIFI, Bluetooth Low Energy (BLE), Near Field Communications (NFC), and the like. The ad-hoc wireless networks spontaneously form based on geographic proximity that triggers the automatic creation of point-to-point links and associated networking capabilities. For example, a pair of proximate smartphones may discover one another and establish WIFI links to form an ad-hoc wireless network. A newly arriving smartphone may discover the existing pair and establish new WIFI links with each smartphone to grow the ad-hoc wireless network. Additional smartphones may join the ad-hoc wireless network in a like manner.

[0005] The wireless user devices may host user applications that use the ad-hoc wireless networks. For example, vehicle-transceivers may host anti-collision Vehicle-to-Vehicle (V2V) applications that use ad-hoc wireless networks among proximate vehicles to avoid crashes. In another example, a gamer's smart-goggles may host a user application that uses an ad-hoc wireless network to interact with other nearby smart-goggles to present interactive gameplay to multiple gamers.

[0006] The wireless user devices interact with wireless network cores to obtain network services like internet access and data messaging. The wireless user devices also interact with one another to obtain wireless ad-hoc services like interactive gaming. The wireless network cores help the ad-hoc wireless networks by authorizing the wireless user devices and scheduling resources for the wireless user devices. Unfortunately, the wireless network cores do not effectively interact with the wireless user devices to support the user applications that use the ad-hoc wireless networks. Moreover, the wireless user devices do not efficiently interact with the application users to control their use of their user applications over the ad-hoc wireless networks.

## TECHNICAL OVER VIEW

[0007] In some examples, a communication system comprises one or more wireless access nodes and an application server. The one or more wireless access nodes wirelessly receive a network identifier for a communication network and transfer the network identifier to the application server. The one or more wireless access nodes wirelessly receive an application identifier for a user application that uses the communication network and transfer the application identifier to the application server. The application server associates the application identifier with the network identifier. The one or more wireless access nodes wirelessly receive an application username that identifies a user of the user application and transfer the application username to the application server. The application server associates the application username with the application identifier. The one or more wireless access nodes wirelessly receive a request that indicates the network identifier and transfer the request to the application server. The application server transfers the application username associated with the application identifier and the application identifier associated with the network identifier to the one or more wireless access nodes in response to the request. The one or more wireless access nodes wirelessly transfer the application username associated with the application identifier and the application identifier associated with the network identifier in response to the request.

[0008] In some examples, a method comprises the following operations. Authenticate a user apparatus that has a user application that uses a communication network. Receive a network identifier for the communication network and an application identifier for the user application from the user apparatus. Receive an application username for a user of the user application from the user apparatus. Authenticate another user apparatus that has the user application. Receive a request that indicates the network identifier from the other user apparatus, and in response, transfer the application identifier and the application username to the other user apparatus.

[0009] In some examples, a method comprises the following operations. Receive a network identifier for a communication network from a user apparatus. Receive an application identifier for a user application that uses the communication network from the user apparatus. Receive an application username that identifies a user of the user application from the user apparatus. Receive a request that indicates the network identifier from another user apparatus, and in response, transfer the application identifier and the application username to the other user apparatus.

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## Description

### DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 illustrates an exemplary wireless communication system to deliver user applications to spatial compute devices over ad-hoc communication networks.

[0011] FIG. 2 illustrates an exemplary operation of the wireless communication system to deliver the user applications to the spatial compute devices over the ad-hoc communication networks.

[0012] FIG. 3 illustrates an exemplary operation of the wireless communication system to deliver the user applications to the spatial compute devices over the ad-hoc communication networks.

[0013] FIG. 4 illustrates an exemplary Fifth Generation (5G) communication network to deliver user applications to spatial compute devices over ad-hoc communication networks.

[0014] FIG. 5 illustrates the exemplary 5G communication network to deliver the user applications to the spatial compute devices over the ad-hoc communication networks.

[0015] FIG. 6 illustrates an exemplary spatial compute device in the 5G communication network.

[0016] FIG. 7 illustrates exemplary access nodes in the 5G communication network.

[0017] FIG. 8 illustrates an exemplary data center in the 5G communication network.

[0018] FIG. 9 illustrates an exemplary operation of the 5G communication network to deliver the user applications to the spatial compute devices over the ad-hoc communication networks.

[0019] FIG. **10** illustrates an exemplary operation of the 5G communication network to deliver the user applications to the spatial compute devices over the ad-hoc communication networks.

#### DETAILED DESCRIPTION

[0020] FIG. **1** illustrates exemplary wireless communication system **100** to deliver user applications to spatial compute devices **101-108** over ad-hoc communication networks **121-122**. Wireless communication system **100** comprises spatial compute devices **101-108**, access networks **120**, ad-hoc communication networks **121-122**, and application server system **130**. Spatial compute devices **101-108** comprise phones, computers, goggles, controllers, and/or some other user apparatus with communication circuitry that is configured to operate as described below. The user applications are designated alphabetically and may comprise gaming applications, Augmented Reality (AR) applications, Virtual Reality (VR) applications, and/or some other type of user software.

[0021] Access networks **120** comprise wireless networks, wireline networks, satellite systems, and/or some other type of data communication equipment. Ad-hoc networks **121-122** comprise point-to-point wireless links between pairs of spatial compute devices **101-108** that are rapidly formed based on public standards and geographic proximity. Ad-hoc networks **121-122** may use Fifth Generation New Radio (5G NR), Direct Short Range Radio Communication (DSRC), Institute of Electrical and Electronic Engineers (IEEE) 802.11 (WIFI), Bluetooth Low Energy (BLE), Near Field Communications (NFC), and/or some other ad-hoc networking protocol. Application server system **130** comprises one or more networked computers with communication and database software that are configured to operate as described below. Application server system **130** maintains a data structure that associates individual application users with their individual user applications. The data structure also associates the individual user applications with their individual ad-hoc communication networks.

[0022] Various examples of network operation and configuration are described herein. In some examples, spatial compute devices **101-107** wirelessly form ad-hoc communication networks **121-122** while spatial compute device **108** (represented by dotted lines) is still located away from ad-hoc communication networks **121-122**. Spatial compute devices **101-107** wirelessly exchange application data between user applications A-C for application users **1-7** over ad-hoc communication networks **121-122**. Spatial compute devices **101-107** individually transfer network data to application server system **130** over access networks **120** that indicates: 1) the individual ad-hoc communication networks **121-122** that they currently use, 2) the user applications A-C that they currently use over ad-hoc communication networks **121-122**, and 3) the individual application users **1-7** that currently use individual user applications A-C over the individual ad-hoc networks **121-122**. Individual application users are typically identified by self-selected usernames, although other user indicators could be used. Application server system **130** receives and stores the network data.

[0023] As indicated by arrow #1, spatial compute device **108** (now represented by solid bold lines) moves toward and wirelessly detects ad-hoc communication network **122**. As indicated by arrow #2, spatial compute device **108** responsively transfers a network query to application server system **130** over access networks **120** that indicates detected ad-hoc communication network **122**.

Application server system **130** receives the network query and responsively translates an identifier for ad-hoc communication network **123** into information for a network response that indicates user application A and its current application users **5-7** along with user application C and its current application users **5-6**. As indicated by arrow #2, application server system **130** transfers the network response to spatial compute device **108**. Spatial compute device **108** receives the network response and responsively presents that application users **5, 6**, and **7** are using user application A over ad-hoc communication network **122**, and that application users **5** and **6** are using user application C over ad-hoc communication network **122**. In response, spatial compute device **108** receives a user selection of user application A. As indicated by lines #3, spatial compute device **108**

establishes point-to-point links with spatial compute devices **105-107** to join ad-hoc communication network **122**. Application user **8** in spatial compute device **108** wirelessly exchanges application data for selected user application A with application users **5, 6, and 7** over ad-hoc communication network **122**. As indicated by arrow **#4**, spatial compute device **108** transfers network data to application server system **130** that indicates that application user **8** is currently using user application A over ad-hoc network **122**. Application server system **130** receives, stores, and subsequently serves the new network data for ad-hoc communication network **122**.

[0024] Advantageously, wireless communication system **100** effectively interacts with spatial compute devices **101-108** to support user applications A-C that use ad-hoc communication networks **121-122**. Moreover, spatial compute devices **101-108** efficiently interact with application users **1-8** to control their use of ad-hoc communication networks **121-122** and user applications A, B, and C.

[0025] In some examples, spatial compute device **108** presents a network option to use application server system **130** for user applications A or C instead of ad-hoc communication network **122**. Spatial compute device **108** may receive a user selection of the network option with users **5-7** and establish connectivity to application users **5-7** in spatial compute devices **105-107** through application server system **130**. Application user **8** in spatial compute device **108** then exchanges application data for user application A with the same users over application server system **130** instead of ad-hoc communication network **122**. Spatial compute device **108** may also receive a user selection of another network option to establish connectivity to different application users of the user application through application server system **130**.

[0026] Spatial compute devices **101-108** comprise radios that wirelessly communicate using wireless protocols like 5G NR, DSRC, WIFI, BLE, NFC, Low-Power Wide Area Network (LP-WAN), Code Division Multiple Access (CDMA), Frequency Division Multiple Access (FDMA), and Time Division Multiple Access (TDMA). Spatial compute devices **101-108** and application server system **130** comprise microprocessors, software, memories, transceivers, bus circuitry, and the like. The microprocessors comprise Digital Signal Processors (DSP), Central Processing Units (CPU), Graphical Processing Units (GPU), Application-Specific Integrated Circuits (ASIC), and/or the like. The memories comprise Random Access Memory (RAM), flash circuitry, disk drives, and/or the like. The memories store software like operating systems, user applications, radio applications, and network applications. The microprocessors retrieve the software from the memories and execute the software to drive the operation of wireless communication system **100** as described herein.

[0027] FIG. **2** illustrates an exemplary operation of wireless communication system **100** to deliver user applications to spatial compute devices **101-108** over ad-hoc communication networks **121-122**. The operation may vary in other examples. Spatial compute devices **101-107** wirelessly form ad-hoc communication networks **121-122** that comprise point-to-point connections between spatial compute devices **101-107** (**201**). Spatial compute devices **101-107** wirelessly exchange application data between the user applications for the application users A-C over ad-hoc communication networks **121-122** (**202**). Spatial compute devices **101-107** transfer network data to application server system **130** over access networks **120** that indicates: the individual ad-hoc communication networks **121-122** that they currently use, the individual user applications A-C that they currently use over which individual ad-hoc communication networks **121-122**, and the individual application users **1-7** that are currently using which user applications A-C (**203**). Application server system **130** receives and stores the network data (**204**). New spatial compute device **108** wirelessly detects ad-hoc communication network **122** and transfers a network query to application server system **130** over access networks **120** that indicates detected ad-hoc communication network **122** (**205**). Application server system **120** receives the network query and responsively transfers a network response that indicates the current user applications and their current application users for ad-hoc

communication network **122** (206). Application server system **130** transfers the network response to new spatial compute device **108** (206). New spatial compute device **108** receives the network response and graphically presents the individual application users that are the individual user applications over ad-hoc communication network **122** (206). New spatial compute device **108** receives a user selection of user application A over ad-hoc communication network **122** and establishes point-to-point wireless links with spatial compute devices **105-107** in ad-hoc communication network **122**. New spatial compute device **108** wirelessly exchanges application data for the selected user application A with spatial compute devices **105-107** over ad-hoc communication network **122** (207).

[0028] FIG. 3 illustrates an exemplary operation of the wireless communication system **100** to deliver the user applications to spatial compute devices **101-108** the over ad-hoc communication networks **121-122**. The operation may vary in other examples. Spatial compute devices **101-104** wirelessly form ad-hoc communication network **121**. Spatial compute devices **101-104** wirelessly exchange application data over ad-hoc communication network **121**. Spatial compute devices **105-107** wirelessly form ad-hoc communication network **122**. Spatial compute devices **105-107** wirelessly exchange application data over ad-hoc communication network **122**. Spatial compute devices **101-107** transfer network data to application server system **130** that indicates their individual apps A-C and their individual application users **1-7** for ad-hoc networks **121-122**. The indication of application users **1-7** comprises self-selected usernames by the users of spatial compute devices **101-107** or some other user identifiers.

[0029] Spatial compute device **108** wirelessly detects ad-hoc communication network **122** and transfers a network query to application server system **130** for ad-hoc communication network **122**. Application server system **130** transfers a response to spatial compute device **108** that indicates the individual application users and the individual user applications for ad-hoc communication network **122**. Spatial compute device **108** receives the network response and selects user application A in ad-hoc communication network **122**-typically after a graphic interaction with the user. Spatial compute device **108** establishes point-to-point wireless links with spatial compute devices **105-107** to join ad-hoc communication network **122**. Spatial compute device **108** transfers network data to application server system **130** that indicates that application user **8** is currently using user application A over ad-hoc network **122**. The indication of application user **8** comprises a self-selected username by the user of spatial compute device **108** or some other user identifier. Application users **1-4** in spatial compute devices **101-104** wirelessly exchange application data for their user applications over ad-hoc communication network **121**. Application users **5-8** of spatial compute devices **105-108** wirelessly exchange application data for their user applications over ad-hoc communication network **122**.

[0030] FIG. 4 illustrates exemplary Fifth Generation (5G) communication network **400** to deliver user applications to spatial compute devices (DEV.) **401-407** over ad-hoc communication networks A and B. 5G communication system **400** comprises an example of wireless communication system **100**, although system **100** may differ. 5G communication system **400** comprises: spatial compute devices **401-407**, Access Nodes (ANs) **411-412**, and network data center **420**. Network data center **420** comprises Access and Mobility Management Function (AMF) **421**, Session Management Function (SMF) **422**, User Plane Function (UPF) **423**, Application Server Function (ASF) **424**, and Interworking Function (IWF) **425**. Network data center **420** typically includes additional network functions like Network Repository Function (NRF) and Unified Data Management (UDM) that are omitted for clarity.

[0031] Spatial compute device **401** wirelessly attaches to 5G NR AN **411**. Spatial compute device **401** registers with AMF **421** over 5G NR AN **411**. AMF **421** authenticates and authorizes spatial compute device **401** for data services that include connectivity to ASF **424**. AMF **421** transfers spatial compute device context for the services for spatial compute device **401** to SMF **423**, and SMF **423** transfers the spatial compute device context to UPF **423**. AMF **421** transfers spatial

compute device context for the services for spatial compute device **401** to 5G NR AN **411**, and 5G NR AN **411** transfers the spatial compute device context to spatial compute device **401**. To initiate a Virtual Reality (VR) application with other spatial compute devices, spatial compute device **401** broadcasts a beacon for ad-hoc network A. Over 5G NR AN **411** and UPF **423**, spatial compute device **401** notifies ASF **424** of the VR application that is available over ad-hoc communication network A along with the VR application username for spatial compute device **401**. The user of spatial compute device **401** selects a network name for ad-hoc communication network A and the VR application username.

[0032] Spatial compute device **402** wirelessly attaches to 5G NR AN **411**. Spatial compute device **402** registers with AMF **421** over 5G NR AN **411**. AMF **421** authenticates and authorizes spatial compute device **402** for services that include connectivity to ASF **424**. AMF **421** transfers spatial compute device context for the services for spatial compute device **402** to SMF **423**, and SMF **423** transfers the spatial compute device context to UPF **423**. AMF **421** transfers spatial compute device context for the services for spatial compute device **402** to 5G NR AN **411**, and 5G NR AN **411** transfers the spatial compute device context to spatial compute device **402**. Spatial compute device **401** detects ad-hoc communication network A and queries ASF **424** for corresponding information over 5G NR AN **411** and UPF **423**. ASF **424** translates ad-hoc communication network A into the VR application and VR application username for spatial compute device **401**. ASF **424** indicates the VR application on ad-hoc communication network A and the VR application username for spatial compute device **401** to spatial compute device **402**. Spatial compute device **402** displays a prompt to use the VR application with the VR application username for spatial compute device **401** over ad-hoc communication network A. In response, spatial compute device **402** receives a user instructions to join ad-hoc communication network A and use the VR application with a select VR application username. Spatial compute devices **401-402** establish point-to-point 5G NR link **411**. Spatial compute devices **401-402** exchange VR application data over 5G NR link **411** in ad-hoc communication network A. Spatial compute device **402** notifies ASF **424** of its VR application username and its use of the VR application over ad-hoc communication network A.

[0033] Spatial compute device **403** wirelessly attaches to 5G NR AN **411**. Spatial compute device **403** registers with AMF **421** over 5G NR AN **411**. AMF **421** authenticates and authorizes spatial compute device **403** for services that include connectivity to ASF **424**. AMF **421** transfers spatial compute device context for the services for spatial compute device **403** to SMF **423**, and SMF **423** transfers the spatial compute device context to UPF **423**. AMF **421** transfers spatial compute device context for the services for spatial compute device **403** to 5G NR AN **411**, and AN **411** transfers the spatial compute device context to spatial compute device **403**. Spatial compute device **403** detects ad-hoc communication network A and queries ASF **424** over 5G NR AN **411** and UPF **423**. ASF **424** translates ad-hoc communication network A into the VR application and the VR application usernames for spatial compute devices **401-402**. ASF **424** indicates the VR application on ad-hoc communication network A and the VR application usernames for spatial compute devices **401-402** to spatial compute device **403**. Spatial compute device **403** displays a prompt to use the VR application with the VR application usernames for spatial compute devices **401-402** over ad-hoc communication network A. In response, spatial compute device **403** receives user instructions to join ad-hoc communication network A and use the VR application. Spatial compute device **403** establishes point-to-point 5G NR links **412-413** with respective spatial compute devices **401-402**. Spatial compute devices **401-403** exchange VR application data over 5G NR links **411-413** in ad-hoc communication network A. Spatial compute device **403** notifies ASF **424** of its VR application username and its use of the VR application over ad-hoc communication network A. Spatial compute devices **401-403** may use additional applications over ad-hoc communication network A in a like manner.

[0034] Spatial compute device **404** wirelessly attaches to WIFI AN **412**. Spatial compute device **404** establishes a secure tunnel with IWF **425** over WIFI AN **412**. Spatial compute device **404**

registers with AMF **421** over WIFI AN **412** and IWF **425**. AMF **421** authenticates and authorizes spatial compute device **404** for data services that include connectivity to ASF **424**. AMF **421** transfers spatial compute device context for the services for spatial compute device **404** to SMF **423**, and SMF **423** transfers the spatial compute device context to UPF **423**. AMF **421** transfers spatial compute device context for the services for spatial compute device **404** to IWF **425** and to spatial compute device **404** over IWF **425** and WIFI AN **412**. To initiate an interactive gaming application with other spatial compute devices, spatial compute device **404** broadcasts a beacon for ad-hoc communication network B. Over WIFI AN **412**, IWF **425**, and UPF **423**, spatial compute device **404** notifies ASF **424** of the interactive gaming application that is available over ad-hoc communication network B along with the gaming application username for spatial compute device **404**.

[0035] Spatial compute device **405** wirelessly attaches to WIFI AN **412**. Spatial compute device **405** establishes a secure tunnel with IWF **425** over WIFI AN **412**. Spatial compute device **405** registers with AMF **421** over WIFI AN **412** and IWF **425**. AMF **421** authenticates and authorizes spatial compute device **405** for services that include connectivity to ASF **424**. AMF **421** transfers spatial compute device context for the services for spatial compute device **405** to SMF **423**, and SMF **423** transfers the spatial compute device context to UPF **423**. AMF **421** transfers spatial compute device context for the services for spatial compute device **405** to IWF **425** and to spatial compute device **405** over IWF **425** and WIFI AN **412**. Spatial compute device **405** detects ad-hoc communication network B and queries ASF **424** for corresponding information over WIFI AN **411**, IWF **425**, and UPF **423**. ASF **424** translates ad-hoc communication network B into the interactive gaming application and gaming application username for spatial compute device **404**. ASF **424** indicates the interactive gaming application on ad-hoc communication network B and the gaming application username for spatial compute device **404** to spatial compute device **405**. Spatial compute device **405** displays a prompt to use the interactive gaming application with the gaming application username for spatial compute device **404** over ad-hoc communication network B. In response, spatial compute device **405** receives a user instruction to join ad-hoc communication network B and use the interactive gaming application. Spatial compute devices **404-405** establish point-to-point Direct Short Range Radio Communication (DSRC) link **414**. Spatial compute devices **404-405** exchange interactive gaming application data over DSRC link **414** in ad-hoc communication network B. Spatial compute device **405** notifies ASF **424** of its gaming application username and its use of the interactive gaming application over ad-hoc communication network B.

[0036] Spatial compute device **406** wirelessly attaches to WIFI AN **412**. Spatial compute device **406** establishes a secure tunnel with IWF **425** over WIFI AN **412**. Spatial compute device **406** registers with AMF **421** over WIFI AN **412** and IWF **425**. AMF **421** authenticates and authorizes spatial compute device **406** for services that include connectivity to ASF **424**. AMF **421** transfers spatial compute device context for the services for spatial compute device **406** to SMF **423**, and SMF **423** transfers the spatial compute device context to UPF **423**. AMF **421** transfers spatial compute device context for the services for spatial compute device **406** to IWF **425** and to spatial compute device **406** over IWF **425** and WIFI AN **412**. Spatial compute device **406** detects ad-hoc communication network B and queries ASF **424** for corresponding information over WIFI AN **411**, IWF **425**, and UPF **423**. ASF **424** translates ad-hoc communication network B into the interactive gaming application and gaming application usernames for spatial compute devices **404-405**. ASF **424** indicates the interactive gaming application on ad-hoc communication network B and the gaming application usernames for spatial compute devices **404-405** to spatial compute device **406**. Spatial compute device **406** displays a prompt to use the interactive gaming application with the gaming application usernames for spatial compute devices **404-405** over ad-hoc communication network B. In response, spatial compute device **406** receives a user instruction to join ad-hoc communication network B and use the interactive gaming application. Spatial compute device **406** and spatial compute devices **404-405** establish respective DSRC links **415-416**. Spatial compute



devices **404-406** exchange interactive gaming application data over DSRC links **414-416** in ad-hoc communication network B. Spatial compute device **406** notifies ASF **424** of its gaming application username and its use of the interactive gaming application over ad-hoc communication network B. Spatial compute devices **404-406** may use additional applications over ad-hoc communication network B in a like manner. The description continues below with respect to FIG. 5.

[0037] FIG. 5 illustrates exemplary 5G communication network **400** to serve spatial compute devices **401-407** over ad-hoc communication networks A and B. The description of FIG. 5 follows from the above description of FIG. 4. Spatial compute device **407** attaches 5G NR AN **411** over 5G NR link **517** and/or to WIFI AN **412** over WIFI link **518**. Spatial compute device **407** registers with AMF over 5G NR AN **411** and/or WIFI AN **412** and IWF **425**. Spatial compute device **407** interacts with ASF **424** over 5G NR AN **411** and UPF **423** and/or WIFI AN **412**, IWF **425**, and UPF **423**. Spatial compute device **407** detects both ad-hoc communication networks A and B. Spatial compute device **407** queries ASF **424** for information for ad-hoc communication networks A and B. ASF **424** translates ad-hoc communication network A into the VR application, the VR application usernames for spatial compute devices **401-403**, and ad-hoc communication network A. ASF **424** translates ad-hoc communication network B into the interactive gaming application, the gaming application usernames for spatial compute devices **404-406**, and ad-hoc communication network B.

[0038] ASF **424** indicates the VR application on ad-hoc network A and the VR application usernames for spatial compute devices **401-403** to spatial compute device **407**. ASF **424** further indicates the interactive gaming application on ad-hoc network B and the gaming application usernames for spatial compute devices **404-406** to spatial compute device **407**. Spatial compute device **407** displays a prompt to use the VR application with the gaming application usernames for spatial compute devices **401-403** over ad-hoc communication network A. Spatial compute device **407** displays another prompt to use the interactive gaming application with the gaming application usernames for spatial compute devices **404-406** over ad-hoc communication network B. In response, spatial compute device **407** receives user instructions to join ad-hoc communication network A and use the VR application and to join ad-hoc communication network B and use the interactive gaming application. Spatial compute device **407** and spatial compute devices **401-403** establish respective 5G NR links **511-513**. Spatial compute devices **401-403** and **407** exchange VR application data over 5G NR links **411-413** and **511-513** in ad-hoc communication network A. Spatial compute device **407** and spatial compute devices **404-406** establish respective DSRC links **514-516**. Spatial compute devices **404-407** exchange interactive gaming application data over DSRC links **414-416** and **514-516** in ad-hoc communication network B. Spatial compute device **407** notifies ASF **424** of its VR application username and its use of the VR application over ad-hoc communication network A. Spatial compute device **407** also notifies ASF **424** of its gaming application username and its use of the interactive gaming application over ad-hoc communication network B. Spatial compute device **407** may use additional applications over ad-hoc communication networks A and B in a like manner. Spatial compute device **407** may interact with ASF **424** over WIFI AN **412**, IWF **425**, and UPF **423** instead of 5G NR AN **411**.

[0039] In some examples, spatial compute device **407** interacts with spatial compute devices **401-406** over ASF **424** instead of ad-hoc networks A and B. For example, spatial compute device **407** may interact with spatial compute devices **401-403** over ASF **424** instead of ad-hoc network A—and spatial compute devices **401-403** and **407** may use either the WIFI link (WIFI AN **412**-IWF **425**-UPF **423**) or the 5G NR link (5G NR AN **411**-UPF **423**) to access ASF **424**. Spatial compute device **407** may interact with spatial compute devices **404-406** over ASF **424** instead of ad-hoc network B—and spatial compute devices **404-407** may use either the WIFI link or the 5G NR link to access ASF **424**. The use of ad-hoc networks A-B or ANs **411-412** for the individual user applications and application usernames is controlled by the user of spatial compute device **407** and may be automatically selected by spatial compute device **407** based on data communication quality. Spatial compute devices **401-406** and other spatial compute devices could be configured and

operate like spatial compute device **407**.

[0040] FIG. **6** illustrates exemplary spatial compute device **407** in 5G communication network **400**. Spatial compute device **407** comprises an example of spatial compute devices **101-108** and **401-406**, although spatial compute devices **101-108** and **401-406** may differ. Spatial compute device **407** comprises 5G NR radios **601-602**, WIFI radio **603**, DSRC radio **604**, user components **605**, and processing circuitry **606**. Radios **601-604** comprise antennas, amplifiers, filters, modulation, analog-to-digital interfaces, DSP, memory, and transceivers that are coupled over bus circuitry. User components **605** comprise displays, speakers, microphones, controllers, and/or some other user apparatus. Processing circuitry **606** comprises CPU, memory, and transceivers (XCVRs) that are coupled over bus circuitry. The memory in processing circuitry **606** stores an operating system (OS), Third Generation Partnership Project applications (3GPP), 5G NR applications (5G NR), DSRC applications (DSRC), WIFI applications (WIFI), and user applications (APP) for gaming, VR, and AR.

[0041] The antennas in 5G NR radio **601** exchange 5G NR signals with 5G NR AN **411**. The antennas in 5G NR radio **602** exchange 5G NR signals with spatial compute devices **401-403** over ad-hoc network A. The antennas in WIFI radio **603** exchange WIFI signals with WIFI AN **412**. The antennas in DSRC radio **604** exchange DSRC signals with spatial compute devices **404-406** over ad-hoc network B. User components **605** and the transceivers in radios **601-604** are coupled to transceivers in processing circuitry **606**. In processing circuitry **606**, the CPU retrieves the operating system and applications from the memory and executes the operating system and applications to operate spatial compute device **407** as described herein.

[0042] FIG. **7** illustrates exemplary 5G NR AN **411** and WIFI AN **412** in 5G communication network **400**. ANs **411-412** comprise examples of access networks **120**, although networks **120** may differ. 5G NR AN **411** comprises 5G NR Radio Unit (RU) **701**, Distributed Unit (DU) **702**, and Centralized Unit (CU) **703**. 5G NR RU **701** comprises antennas, amplifiers, filters, modulation, analog-to-digital interfaces, DSP, memory, radio applications, and transceivers that are coupled over bus circuitry. DU **702** comprises memory, CPU, user interfaces and components, and transceivers that are coupled over bus circuitry. The memory in DU **702** stores operating system and 5G NR network applications for physical layer, media access control, and radio link control. CU **703** comprises memory, CPU, and transceivers that are coupled over bus circuitry. The memory in CU **703** stores an operating system and 5G NR network applications for packet data convergence protocol, service data adaptation protocol, and radio resource control.

[0043] The antennas in 5G NR RU **701** are wirelessly coupled to spatial compute devices **401-403** and **407** over 5G NR links. Transceivers in 5G NR RU **701** are coupled to transceivers in DU **702**. Transceivers in DU **702** are coupled to transceivers in CU **703**. Transceivers in CU **703** are coupled to AMF **421** and UPF **423**. The DSP and CPU in RU **701**, DU **702**, and CU **703** execute the radio applications, operating systems, and network applications to exchange data and signaling with spatial compute devices **401-403**, spatial compute device **407**, AMF **421**, and UPF **423**. In particular, the 5G NR radio resource control in CU **703** may schedule 5G NR resource blocks between spatial compute devices to form point-to-point 5G NR links **411-413** and **511-513**.

[0044] WIFI AN **412** comprises WIFI radio **705** and node circuitry **706**. WIFI radio **705** comprises antennas, amplifiers, filters, modulation, analog-to-digital interfaces, DSP, memory, radio applications, and transceivers that are coupled over bus circuitry. Node circuitry **706** comprises memory, CPU, and transceivers that are coupled over bus circuitry. The memory in node circuitry **706** stores operating system and WIFI applications. The antennas in WIFI radio **705** are wirelessly coupled to spatial compute devices **404-407** over WIFI links. Transceivers in WIFI radio **705** are coupled to transceivers in node circuitry **706**. Transceivers in node circuitry **706** are coupled to IWF **425**. The CPU in node circuitry **706** execute the WIFI applications and operating systems to exchange data and signaling with spatial compute devices **404-407** and IWF **425**.

[0045] FIG. **8** illustrates exemplary data center **420** in 5G communication system **400**. Network

data center **420** comprises an example of access networks **120** and application server system **130**, although networks **120** and system **130** may differ. Network data center **420** comprises Network Function (NF) hardware **801**, NF hardware drivers **802**, NF operating systems **803**, NF virtual layer **804**, and NF Software (SW) **805**. NF hardware **801** comprises Network Interface Cards (NICs), CPU, RAM, Flash/Disk Drives (DRIVE), and Data Switches (DSW). NF hardware drivers **802** comprise software that is resident in the NIC, CPU, RAM, DRIVE, and DSW. NF operating systems **803** comprise kernels, modules, and applications that form containers for virtual layer and NF software execution. NF virtual layer **804** comprises vNIC, vCPU, vRAM, vDRIVE, and vSW. NF SW **805** comprises AMF SW **821**, SMF SW **822**, UPF SW **823**, ASF SW **824**, and IWF SW **825**. Other NF SW like Network Repository Function (NRF) SW is typically present but is omitted for clarity. Network data center **420** may be located at a single site or be distributed across multiple geographic locations. The NIC in NF hardware **801** are coupled to 5G NR AN **411**, WIFI AN **412**, and external systems. NF hardware **801** executes NF hardware drivers **802**, NF operating systems **803**, NF virtual layer **804**, and NF SW **805** to form and operate AMF **421**, SMF **422**, UPF **423**, ASF **424**, and IWF SW **425** as described herein. In particular, AMF **421**, SMF **422**, UPF **423**, and IWF **425** serve spatial compute device access to ASF **424**. ASF **424** serves user application information for ad-hoc networks including the individual application users. ASF **424** also serves connectivity for some user applications and hosts other user applications.

[0046] FIG. **9** illustrates an exemplary operation of 5G communication network **400** to deliver user applications to spatial compute devices (DEV.) **401-407** over the ad-hoc communication networks A and B. The operation may differ in other examples. Representative user applications **1-2** are used in this example, and user applications **1-2** could be for gaming, AR, VR, or some other user service. Spatial compute devices **401-403** form ad-hoc communication network A, execute user application **1**, and exchange application **1** data over point-to-point 5G NR links. Spatial compute devices **404-406** form ad-hoc communication network B, execute user application **2**, and exchange application **2** data over point-to-point DSRC links. Spatial compute devices **404-406** individually report their use of network application **2**, ad-hoc communication network B, and their own application **2** usernames to ASF **424** over WIFI AN **412**, IWF **425**, and UPF **423**. Spatial compute devices **401-403** individually report their use of network application **1**, ad-hoc communication network A, and their own application **1** usernames to ASF **424** over 5G NR AN **411** and UPF **423**.

[0047] Spatial compute device **407** detects ad-hoc communication network B and queries ASF **424** over 5G NR AN **411** and UPF **423**. ASF **424** translates ad-hoc network B into user application **2** and its application **2** usernames. ASF **424** responds to spatial compute device **407** with user application **2** and its application **2** usernames for ad-hoc communication network B. In response to a user prompt and selection, spatial compute device **407** joins ad-hoc communication network B and executes user application **2**. Spatial compute devices **401-403** and **407** exchange data for user application **2** over ad-hoc communication network B. For example, user application **2** could be a VR application, and the VR application usernames could share VR application data over ad-hoc communication network B.

[0048] Spatial compute device **407** detects ad-hoc communication network A and queries ASF **424** over 5G NR AN **411** and UPF **423**. ASF **424** translates ad-hoc network A into user application **1** and its application usernames. ASF **424** responds to spatial compute device **407** with user application **1** and its application usernames for ad-hoc communication network A. In response to a user prompt and selection, spatial compute device **407** joins ad-hoc communication network A and executes user application **1**. Spatial compute devices **401-403** and **407** exchange data for user application **1** over ad-hoc communication network A. For example, user application **1** could be an interactive gaming application and the gaming application usernames share gaming application data over ad-hoc communication network A.

[0049] FIG. **10** illustrates an exemplary operation of 5G communication network **400** to deliver the user applications to spatial compute devices (DEV.) **401-407** over ad-hoc communication networks

A and B. The operation may differ in other examples. Spatial compute devices **404-406** form ad-hoc communication network B and execute user application 2. Spatial compute devices **404-406** individually report their use of network application 2, ad-hoc communication network B, and their own application usernames to ASF **424**. Spatial compute device **407** detects ad-hoc communication network B and queries ASF **424** over 5GNR AN **411** and UPF **423**. ASF **424** translates ad-hoc communication network B into user application 2 and its application 2 usernames. ASF **424** responds to spatial compute device **407** with user application 2 and its application 2 usernames for ad-hoc communication network B. Spatial compute device **407** joins ad-hoc communication network B and executes user application 2. Spatial compute devices **401-403** and **407** exchange data for user application 2 over ad-hoc communication network B. For example, user application 2 could be an AR application and the AR application usernames share AR application data over ad-hoc communication network A.

[0050] Spatial compute device **407** receives a user instruction to use ASF **424** to interact with spatial compute devices **404-406** for user application 2. In response, spatial compute device **407** interacts with spatial compute devices **404-406** for user application 2 over 5GNR AN **411**, UPF **423**, ASF **424**, UPF **423**, IWF **425**, and WIFI AN **412**. Spatial compute devices **404-406** may opt to use ASF **424** in a similar manner. ASF **424** could host user application 2 for spatial compute devices **404-407** in a client server mode. Spatial compute device **407** then receives a user instruction to use ad-hoc communication network B to interact with spatial compute device **404-406** for user application 2. In response, spatial compute device **407** rejoins ad-hoc communication network B and directly interacts with spatial compute devices **404-406** for user application 2.

[0051] The wireless data network circuitry described above comprises computer hardware and software that form special-purpose wireless network circuitry to serve spatial compute devices over ad-hoc communication networks. The computer hardware comprises processing circuitry like CPUs, DSPs, GPUs, transceivers, bus circuitry, and memory. To form these computer hardware structures, semiconductors like silicon or germanium are positively and negatively doped to form transistors. The doping comprises ions like boron or phosphorus that are embedded within the semiconductor material. The transistors and other electronic structures like capacitors and resistors are arranged and metallurgically connected within the semiconductor to form devices like logic circuitry and storage registers. The logic circuitry and storage registers are arranged to form larger structures like control units, logic units, and Random-Access Memory (RAM). In turn, the control units, logic units, and RAM are metallurgically connected to form CPUs, DSPs, GPUs, transceivers, bus circuitry, and memory.

[0052] In the computer hardware, the control units drive data between the RAM and the logic units, and the logic units operate on the data. The control units also drive interactions with external memory like flash drives, disk drives, and the like. The computer hardware executes machine-level software to control and move data by driving machine-level inputs like voltages and currents to the control units, logic units, and RAM. The machine-level software is typically compiled from higher-level software programs. The higher-level software programs comprise operating systems, utilities, user applications, and the like. Both the higher-level software programs and their compiled machine-level software are stored in memory and retrieved for compilation and execution. On power-up, the computer hardware automatically executes physically-embedded machine-level software that drives the compilation and execution of the other computer software components which then assert control. Due to this automated execution, the presence of the higher-level software in memory physically changes the structure of the computer hardware machines into special-purpose wireless network circuitry to serve spatial compute devices over ad-hoc communication networks.

[0053] The above description and associated figures teach the best mode of the invention. The following claims specify the scope of the invention. Note that some aspects of the best mode may not fall within the scope of the invention as specified by the claims. Those skilled in the art will

appreciate that the features described above can be combined in various ways to form multiple variations of the invention. Thus, the invention is not limited to the specific embodiments described above, but only by the following claims and their equivalents.

## Claims

1. A method comprising: receiving a network identifier for a communication network from a user apparatus; receiving an application identifier for a user application that uses the communication network from the user apparatus; receiving an application username that identifies a user of the user application from the user apparatus; and receiving a request that indicates the network identifier from another user apparatus, and in response, transferring the application identifier and the application username to the other user apparatus.
2. The method of claim 1 further comprising: authenticating the user apparatus; and authenticating the other user apparatus.
3. The method of claim 1 further comprising scheduling wireless communication resources to exchange application data over the communication network between the user apparatus and the other user apparatus.
4. The method of claim 1 further comprising hosting the user application.
5. The method of claim 1 wherein the user application comprises an interactive gaming application.
6. The method of claim 1 wherein the user application comprises an Augmented Reality (AR) application.
7. The method of claim 1 wherein the user application comprises a Virtual Reality (VR) application.
8. The method of claim 1 wherein the user application comprises a Vehicle-to-Vehicle (V2V) application.
9. The method of claim 1 wherein the communication network uses Direct Short Range Radio Communication (DSRC) links.
10. The method of claim 1 wherein the communication network uses Fifth Generation New Radio (5G NR) communication links.
11. The method of claim 1 wherein the communication network uses Wireless Fidelity (WIFI) communication links.
12. The method of claim 1 wherein the communication network uses Bluetooth Low Energy (BLE) communication links.
13. The method of claim 1 wherein the communication network uses Near Field Communication (NFC) links.
14. A method comprising: authenticating a user apparatus that has a user application that uses a communication network; receiving a network identifier for the communication network and an application identifier for the user application from the user apparatus; receiving an application username for a user of the user application from the user apparatus; authenticating another user apparatus that has the user application; and receiving a request that indicates the network identifier from the other user apparatus, and in response, transferring the application identifier and the application username to the other user apparatus.
15. A communication system comprising: one or more wireless access nodes to wirelessly receive a network identifier for a communication network and transfer the network identifier to an application server; the one or more wireless access nodes to wirelessly receive an application identifier for a user application that uses the communication network and transfer the application identifier to the application server; the application server to associate the application identifier with the network identifier; the one or more wireless access nodes to wirelessly receive an application username that identifies a user of the user application and transfer the application username to the application server; the application server to associate the application username with the application

identifier; the one or more wireless access nodes to wirelessly receive a request that indicates the network identifier and transfer the request to the application server; the application server to transfer the application username associated with the application identifier and the application identifier associated with the network identifier to the one or more wireless access nodes in response to the request; and the one or more wireless access nodes to wirelessly transfer the application username associated with the application identifier and the application identifier associated with the network identifier in response to the request.

**16.** The communication system of claim 15 further comprising one or more network functions to authenticate a wireless user device that executes the user application for the user.

**17.** The communication system of claim 15 further comprising the one or more wireless access nodes to schedule wireless communication resources to exchange application data for the user application over the communication network.

**18.** The communication system of claim 15 wherein the user application comprises an interactive gaming application.

**19.** The communication system of claim 15 wherein the user application comprises an Augmented Reality (AR) application.

**20.** The communication system of claim 15 wherein the user application comprises a Virtual Reality (VR) application.

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