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Broadcasting Network and Multicasting Network

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Abstract: *Due to the increasing demand for video and broadcast applications, multicast and broadcast communications are expected to assume a awfully very important role in returning 5G systems. This research trend is attempting to use, extend, or adapt reference transmission ways in which already designed for the conventional 4G technology. withal, apart the 2 reference and standardized methodologies, i.e., Multimedia Broadcast/Multicast Service and Single Cell-Point To Multipoint, several technical extensions and novel solutions were written at intervals the literature to the current purpose. Therefore, so on manufacture a transparent define on accessible solutions (already commonplaceized or just extending normal approaches), this work provides a comprehensive survey on network architectures, communication protocols, transmission strategies, and improvement algorithms to spice up the performance of multicast communications over mobile radio systems. The core of the conducted study represents a structured taxonomy, able to properly classify scientific contributions supported their reference ancient, targeted goal, addressed methodology, considered application domain, and obtained. Taking into thought this taxonomy, quite one hundred of scientific contributions ar given, classified, and reviewed. The study of the state of the art is additional increased with the discussion on necessary lessons learned, that clearly highlight the execs and cons of any investigated approach. attention is also provided on the foremost problems on future Evolution multicasting that require to be higher investigated, and make sure the potential future analysis directions on this subject. the last word goal of this work is to support analysis activities dedicated to the identification of promising methodologies, that with efficiency support the delivery of quantity of some time and on-demand video contents in a TV..*

Keywords: Network, Multicasting Network

I. INTRODUCTION

The explosive growth of good and capable mobile devices unceasingly needs the readying of suitable and wireless communication tecnologies, ready to distribute knowledge to a vast range of users, while making certain Quality of Service (QoS), network capability, spectral potency, and repair responsibleness, as well as terribly low latencies, restricted power consumption, and higher radio resource utilization [1], [2]. To this end, this analysis activities ar that specialize in many innovations which will represent the core of the supposed fifth generation (5G) wireless communication systems [3], [4]. during this context, due to the increasing demand for pervasive video and broadcast-like applications, one-to-many communication schema (i.e., multicast or broadcast communications) are expected to assume a crucial role in future 5G networks [4][6]. Therefore, it's necessary to spot promising methodologies, ready to expeditiously support the delivery of time period and on-demand video contents in an exceedingly . The current analysis trend envisages the chance to leverage (i.e., reuse, extend, or adapt) multicast or broadcast transmission ways already designed (or still beneath development) for the preceding fourth generation (4G) technology, that embody future Evolution (LTE) and future Evolution-Advanced (LTE-A). the 2 reference methodologies ar multimedia system Broadcast/Multicast Service (MBMS) and its evolution, specifically increased multimedia system Broadcast/Multicast Service (eMBMS) or Multicast/Broadcast Single Frequency Network (MBSFN), and Single Cell-Point To Multipoint (SC-PTM). From one aspect, MBMS is standardized by the third Generation Partnership Project (3GPP) [7]. It integrates the MBSFN technology that defines a country spanning over multiple cells, wherever a multicast flow istransmitted altogether of the taking part cells, at the same time and on identical band (i.e., using dedicated, pre-

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planned, and semi-statically organized time slots) [8]. From another aspect, SC-PTM is still beneath standardization and preliminary 3GPP specifications exist already [9].SC- PTM restricts the broadcasting spaceto one cell, permitting a versatile radio resource distribution among unicast and broadcast/multicast flows and supporting a lot of performant physical layer interfaces [10]. At the time of this writing, plenty of scientific contributions already investigated the performances of both MBMS and SC-PTM heterogeneous application domains. See, as an example, the works mentioned in [11]–[14] for MBMS, likewise as [15], [16] for SC-PTM. additionally, the analysis community developed many technical enhancements to the baseline approaches (i.e., those simply standardized by 3GPP). As a consequence, this literature on multicast and broadcast communications over mobile radio systems covers associate explosion of potential candidate techniques and solutions for approaching 5G systems. Based on these premises, this work desires to produce a comprehensive survey on baseline and novel strategies for multicast and broadcast communications over mobile wireless . to the current finish, the scientific literature is analyzed and therefore the offered contributions classified and argued in line with a properly suggested structured graph. 1st ofall, 2 main classes are identified: the primary contains all the works that specialize in MBMS and MBSFN, and therefore the second embraces all the contributions that specialize in SCPTM. Then, for every of those classes, sub- categories are introduced for expeditiously grouping works that leverage similar methodologies and/or reach equivalent goals. within the authors humble opinion, the resulting study offers a transparent summary on the progressive of network architectures, communication protocols, transmission methods, and optimisation algorithms to boost the performance of multicast and broadcast communications over mobile radio systems, and for this reason it may well be terribly helpful for researchers.

II. STANDARDIZED MULTICAST BROADCAST ARCHITECTURES AND FUNCTIONALITIES

According to, the provision of a MBMS service is performed through the subsequent phases:

- Subscription: during this section users comply with receive MBMS services by the suppliers.
- Service Announcement: through this section, all the users associated with the supplier area unit notified of all the offered services.
- Joining: during this section, users become members of a multicast cluster, and comply with receive knowledge of a specific MBMS Bearer Service.
- Session Start: this section indicates the start of a multicast session.
- MBMS Notification: the UE is notified on the start of information transfer.
- Knowledge Transfer: during this section, knowledge area unit effectively delivered to UEs.
- Session Stop: indicates the top of the session since no a lot of knowledge need to be transferred. The bearer resources area unit free during this section.
- Leaving: the user leaves the multicast cluster he/she joined within the connection section. The sequence of phases for the printed mode is that the same of the multicast mode, aside from the Service Subscription, connection and exploit phases, that don't seem to be gift (since they're not necessary for service broadcasting).Illustrates the phases delineate on top of, and includes each the multicast and broadcast modes.The sequence of phases required to produce a MBMS service. Users conform to receive a service (Subscription) and square measure notified of all the on the market services (Service Announcement); then, they be a part of a multicast cluster (Joining) and therefore the multicast session begins (Session Start), notifying UEs on the start of knowledge transfer (Notification). information square measure then transferred to UEs (Data Transfer) till the session ends (Session Stop) and users leave the multicast cluster (Leaving).

Schematization of the MBMS design. The UTRAN provides property between the tip users and therefore the corenetwork (EPC) through the eNBs, which give the physical signal (through antennas), radio resource allocation and repair management to UEs (through the MCE). affiliation to the EPC guarantees management functionalities (through the MME) andmanagement of information science addresses (through the MBMS-GW). The BM-SC interfaces the EPC and therefore the content supplier, performing functionalities of security, service activation and deactivation.

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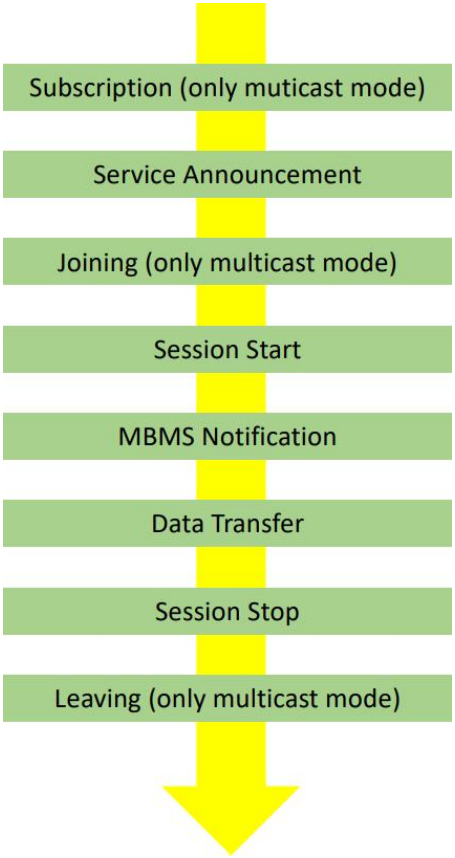

Figure 1. The sequence of phases needed to provide a MBMS service. Users agree to receive a service (Subscription) and are notified of all the available services (Service Announcement); then, they join a multicast group (Joining) and the multicast session begins (Session Start), notifying UEs on the beginning of data transfer (Notification). Data are then transferred to UEs (Data Transfer) until the session ends (Session Stop) and users leave the multicast group (Leaving).

III. RELATED WORK

Here area unit few works within the recent literature wherever a descriptive classification is performed of multicasting ways in wireless networks [12], [16]. Among these, the works do not perform a survey on multicasting; rather, theypropose increased architectures , or discuss the doable challenges and analysis directions in next-generation wireless networks [19]. nonetheless,part of these 2 works is devoted to the analysis of the foremost representative literature on the connected topic. The work [18] analyzes multicasting in WiMAX networks. The goal of this work is to research well Multicast ANd Broadcast Services (MBS) design for WiMAX networks and to propose an increased MBS-based design that may increase the performance of video broadcasting. MBS for WiMAX is analyzed well, in terms of parts and functionalities, proposing enhancements to supply video mobile services, however dedicating solely a quick discussion on MBMS. If compared to the current survey, the goal of is to propose AN design for MBS to boost the standard of video broadcasting in WiMAX networks, and to

not offer a survey of the progressive of MBMS and its evolutions. In fact, MBMS is only superficially introduced and delineate. additionally, deals with WiMAX, that differs from LTE (the central topic of the current survey) in several aspects, since LTE implements important enhancements to supply high quality, wide coverage, higher throughputs and capability, exploiting at best the obtainable spectrum resources, and consequently presents completely differentspecifications in structure and protocols of the stack with reference to WiMAX [11], [10]. Finally,is focused on MBS, which is completely different from MBSFN in LTE (the latter needs synchronicity and rigorous timings needs of transmitted information among adjacent cells).

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IV. AN OVERVIEW OF THE TAXONOMY OF PAPERS ON MBMS, MBSFN AND SC-PTM

Much less efforts area unit created to schedulers that act inside the frequency domain, which can be instead an interesting analysis topic thanks to the intrinsic frequency-selective nature of the channel. An even more interesting effort could also be created by developing schedulers that act in anytime andfrequency domains, to further increase (but complicate) the advance methodology of resource allocation.Coordination among cells to increase SINR ANd rate is ANopen issue for MBSFN. This aspect is important as a results of it'll increase output at cell edge, the network coverage, and thus the suppression of interferenceamong adjacent cells inside the MBSFN area. of those aspects want extra analysis efforts,translating into ways and algorithms attending to reach this goal, at identical time taking into consideration all the management plane procedures which will guarantee the cell synchronization inside the MBSFN area. In this context, analysis got to jointly move towards a cost effective selection of the BSs which will contribute to the creation of a MBSFN area, betting on their mutual position, distance, and transmission power, especially for coverage maximization and interference decrease purposes; to the best of the authors knowledge, this aspect has not been properly taken into consideration inside the works on LTE multicasting. Secure multicast communication is another analysis issue in LTE multicast transmission. The main focus of this subject got to be the guarantee of confidentiality among genuine users in multicast group.

Few efforts area unit created throughout this direction; so, future studies got to purpose on advanced authorization and secret writing mechanisms for multicasting of reserved data. Another fascinating analysis direction could consider anomaly detection algorithms that stop from Denial of Service (DoS) attacks and unauthorized access to multicast groups. There is a sturdy got to use refined simulation/emulation tools that take intoconsideration the most quantity as come-at-able all the layers of the protocol stack and their mutual interactions (through cross-layer analysis),to increase the simulation accuracy. an enquiry effort towards this direction could also be very appreciated to provide extra realistic ends up in fully completely different wise eventualities. to the present end, the tools developed got to take
into account several aspects, i.e., the transmission of varied services in a very MBSFN area, users quality and service continuity, and thus the terminals energy consumption, that area unit nearly neglected altogether the works on this subject. Higher layers parameters got to even be thought of as simulation outputs, to assess the quality of the received data in application eventualities like video multicasting. Optimization algorithms area unit wide used in LTE multicasting to hunt out the solution to several problems, notably inside the context of novel programming techniques,
SE improvement, and subgroup formation ways. the foremost issue is that the problems fairly typically want the advance of extra variables that together contribute to the advance operate, and thus the ESS schema accustomed notice the optimal resolution could also be computationally very pricey. analysis directions throughout this regard aim to hunt out the approximations inside the advance algorithms that change the best trade-off between machine complexity and thus the closeness of the suboptimal resolution to the globally optimum one. This task is not trivial as a results of the accuracy of the search rule chosen depends on several factors, i.e., the number of variables, the structure of the advance operate, the bounds of the search space (if any), etc. and the quality of the rule could also be a key- feature to hunt out the solution in period, which will be a desirable property in wise eventualities. Transmission of compressed video, along with SVC, is that the foremost typically used application state of affairs for service multicasting in LTE. Novel proposals and algorithms got to be evaluated expressly throughout this context. Even if some analysis efforts have already been created throughout this direction, performance of video multicast in MBMS networks got to be evaluated by considering extra video quality metrics, like Structural Similarity, Index Metric (SSIM), the Video Quality Metric (VQM), or the activity analysis of Video Quality (PEVQ), that unit of measurement moredurable to guage and want extra machine efforts than the mostly used PSNR, but provide a extra thorough analysis of the perceived video quality. As regards SC-PTM, tons of less endeavour has been spent if compared to MBSFN, but the bulk the issues addressed on high of keep still valid jointly for single cell multicasting. to boot, a significant issue in this context is AN analysis of the inter- cell interference, that worsens the received multicast signal and the overall transmission performance. Novel error protection and retransmission ways and careful analytical models of transmission aspects that take into consideration this extra complication unit of measurement surely of particular interest throughout this analysis field.

V. BASELINE APPROACHESFOR MBMS

Much less efforts square measure created to schedulers that act within the frequency domain, which may be instead an interesting analysis topic due to the intrinsic frequency-selective nature of the channel. An even more interesting effort

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might even be created by developing schedulers that act in anytime and frequency domains, to further increase (but complicate) the advance methodology of resource allocation. Coordination among cells to extend SINR associated rate is AN open issue for MBSFN. This facet is important as a results of it's going to increase output at cell edge, the network coverage, and so the suppression of interference among adjacent cells within the MBSFN space. of these aspects wish additional analysis efforts, translating into ways that and algorithms going to reach this goal, at identical time taking into thought all the management plane procedures which is able to guarantee the cell synchronization within the MBSFN space. In this context, analysis need to collectively move towards an economical choice of the BSs which is able to contribute to the creation of a MBSFN space, counting on their mutual position, distance, and transmission power, especially for coverage maximization and interference decrease purposes; to the mosteffective of the authors knowledge, this facet has not been properly taken into thought within the works on LTE multicasting. Multicast communication is another analysis issue in LTE multicast transmission. The main focus of this subject need to be the guarantee of confidentiality among real users in multicast group.

Few efforts square measure created throughout this direction; thus, future studies need to purpose on advanced authorization and secret writing mechanisms for multicasting of reserved information. Another fascinating analysis direction could consider anomaly detection algorithms that stop from Denial of Service (DoS) attacks and unauthorized access to multicast teams. There is a durable need to use refined simulation/emulation tools that take into thought the foremost amount as come-at-able all the layers of the protocol stack and their mutual interactions (through cross-layer analysis),to increase the simulation accuracy. a search effort towards this direction might even beterribly appreciated to provide additional realistic winds up in absolutely fully completely different wise eventualities. to this finish, the tools developed need to take into account many aspects, i.e., the transmission of assorted services {in a|during a|in an exceedingly|in a terribly} very MBSFN space, users quality and service continuity, and so the terminals energy consumption, that square measure nearly neglected altogether the works on this subject. Higher layers parameters needto even be thought of as simulation outputs, to assess the standard of the received information in application eventualities like video multicasting. Optimization algorithms square measure wide utilized in LTE multicasting to hunt out the answer to many problems, notably within the context of novel programming techniques, SE improvement, and subgroup formation ways that. the foremost issue is that the issues fairly usually wish the advance of additional variables that along contribute to the advance operate, and so the ESS schema accustomed notice the optimal resolution might even be computationally terribly expensive. analysis directions throughout this regard aim to hunt out the approximations within the advance algorithms that amendment the most effective trade-off between machine complexity and so the closeness of the suboptimal resolution to the globally optimum one. This task isn't trivial as a results of the accuracy of the search rule chosen depends on many factors, i.e., the number of variables, the structure of the advance operate, the bounds of the search area (if any), etc. and the quality of the rule might even be a key-feature to hunt out the answer in amount, which is able to be a fascinating property in wise eventualities. Transmission of compressed video, in conjunction with SVC, is that the foremost usually used application state of affairs for service multicasting in LTE. Novel proposals and algorithms need to be evaluated expressly throughout this context.

VI. SC-PTM TRANSMISSION SCHEMA

6.1 Baseline Approaches

Complementary to MBMS and eMBMS schema, that need a multi-cell atmosphere for coordinated transmission of services, PTM schema considers service multicasting in an exceedingly single cell atmosphere. So, it is very helpful to check these 2 approaches, discussing the professionals and cons of every resolution. In fact, the comparison between SC-PTM and MBSFN, whose quality is testified by the 3GPP studies highlighted in Section II, is mentioned in 2 papers addressing SC- PTM baseline approaches [15], [16]. In [15] both the MBSFN and SC-PTM situations ar analyzed, that specialize in inter-cell interference coordination methods. within the situations analyzed, various factors ar considered: fastened RSs, frequency employ, space diversity and MIMO multiplexing. within the SC- PTM state of affairs, wherever no temporal synchroneity among BSs is assumed, macro-diversity time synchronization is taken into account between the 2 nearest BSs [15]. This study is especially centered on numerical results.

The planned theme is evaluated through town simulations at link level, disbursed per 3GPP specifications. MBSFN and PTM strategies are considered along for the provisioning of MBMS services in [16]. The goal of this work is twofold: a

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performance analysis of the mix of MBSFN and PTM, and a a lot of refined analysis aiming to get a lot of correct results, if compared to the opposite approaches found in literature. To this end, the full transmission value is introduced. Itincludes the value of polling, the value to sight cells with UEs that need to receive a selected MBMS service, the value of the interface for delivering packets to BSs, of synchronization (appearing just for MBSFN transmission scheme) and also the PTM cost that includes the air interfaceand also the packet delivery value at the network nodes [16]. For experimental evaluation, a simulation tool is meant and implemented: it selects the foremost appropriate transmission mode (MBSFN or PTM) that minimizes the full transmission value, counting on the particular LTE configuration User quality in an exceedingly single cell and variable MBSFN areas are taken into consideration.

6.2 Physical Layer Methods

Papers addressing the PTM physical layer analyze MIMO techniques and power and spectrum optimization methods. MIMO and spatial multiplexing ar adopted to cut back BER. methods for power optimization in PTM situations aim at minimizing the transmission power by combining along PtP and PTM transmissions, with the help of cooperation, to avoid wasting energy of the multicasted services. Spectrum is optimized by aggregating the various carriers in an exceedingly LTE-A state of affairs. All the papers exploring these issues ar analyzed with a lot of detail within the following subsections.

1. **MIMO strategies:** The work [144] proposes associate degree adjustive MIMO theme for PTM transmission in LTE. The planned theme focuses on each spatial multiplexing and variety techniques. Spatial diversity is adopted to enhance the signal strength at cell edge to extend the BER performance, while spatial multiplexing is adopted to extend rate and turnout of UEs with sensible channel conditions [144]. totally different spatial multiplexing techniques ar dynamically chosen, supported UEs distributions in the MBMS space
2. **Power improvement methods:** 2 works specialise in power improvement strategies for PTM [14],[12]. In [15] a mechanism is planned, that selects the foremost appropriate radio bearer in eMBMS to optimize the transmission power. The goal of the planned theme is that the step-down of the bachelor's degree transmission power through a wise choice of the foremost appropriate combination of PtP and PTM bearers within the deciliter. This selection depends on associate degree estimation of the optimum coverage in PTM transmission, counting on the UEs distribution within the cell; afterward, the rule decides the PtP bearers that ar used for the remaining parts of the cell [145]. Cooperation between totally different Radio Access Technologies (RATs) is taken into account in [146]. The goal is that the energy saving of multicasted services. the standard state of affairs analyzed during this work is a MG that asks for a service, and is placed in a locality with totally different RATs. Given a MG, with each working cell associated to a RAT that may select PtP or PTM, the target is that the improvement of the general energy consumption [146]. to the present finish, associate degree rule is meant, that has solutions that embody the selection of the operating cell and also the transmission mode (PtP or PTM) per UEs dynamics, at constant time saving energy expeditiously. The improvement downside is developed by suggests that of whole number applied math techniques.
3. **Spectrum improvement strategies:** The work [17] focuses on the state of affairs of ascendable video multicast in LTE-A. The goal of this proposal is to use SC-PTM and eMBMS to transfer MBMS data from the bachelor's degree to a gaggle of UEs over shared resources, exploiting the Carrier Aggregation feature of LTE-A. Functionalities like packet programing,link adaptation, adjustive modulation and committal to writing and HARQ ar performed with reference to every cluster of eMBMS subscribers for thetransmission of ascendable videos, by optimally selecting MCSs for the BL and also the EL of the video, for QoS functions, and proposing independent service objectives for the BL and also the EL. To the present finish, the matter formulation for allocating resources to multicast teams is mentioned, proposing a near-optimal greedy approximation for a good assignment of carriers for the BL and opportunist assignment of carriers for the EL, to maximise throughput.

6.3 Mack Layer Methods

MAC layer methods for PTM schema may be found in [148]–[150]. The work [148] proposes a strategy to modify the signalling procedures in MBMS. The goal of this work is to support streaming and “download-and-play” services to

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UEs, taking into consideration radio and network resources. This task is disbursed through a technique that simplifies the signalling procedure that detects the presence of UEs in an exceedingly cell, in an exceedingly context during which each PtP and PTM with dedicated feedbacks ar supported [148]. The choice of PtP or PTM depends on the quantity of users and also the provided services. The Frequency Domain Packet programing (FDPS) rule is extended in [149] for PTM services. RBs ar dynamically allotted, supported the data on fast channel conditions, with the goal of optimizing the system turnout with a suitable loss of coverage. The planned packet computer hardware acts larva within the time domain, by programing MBMS (re)transmissions in every UTC Interval (TTI), and in the frequency domain, by programing MBMS services on totally different frequencies [149]. Retransmissions ar allowed, however as long as all the UEs of the MG don't acknowledge the packet. totally different RLNC approaches for PTM superimposed service delivery ar planned in [10]. The work depends on the Multirate Transmission (MrT) methods, that enable the delivery of various versions of constant service; thus, they're appropriate for superimposed videos consisting of a BLand multiple ELs, like SVC videos. The planned technique may be a resource allocation theme that aims at optimizingthe transmission theme and minimizing the quantity of broadcast packets, at constant time guaranteeing a satisfactory QoE ofthe user . This goal is achieved by put together optimizing transmission parameters and also the RLNC theme adopted, exploitation packet error likelihood expressions as performance metrics

6.4 Cross-layer methods

Cross-layer approaches for PTM ar mentioned in. In [11] SC-PTM is applied to information broadcasting. the only cell state of affairs is meant, in terms of spec, signalling procedures, radio channel mappings and radio resource management. Then, the planned SC-PTM mechanism is applied to a true LTE-A testbed, consisting of content servers, 2 BSs and 2 mobile terminals, while the implemented multicast services ar streaming, chatting, and aprivate multicast service wherever a mobile terminal transmits video to different users signed to the service [15]. In [12] the problem of mobile TV traffic delivery over OFDMA networks is mentioned. Analytical cross-layer models, supported stochastic process and fixed- point analysis, ar developed 1st for unicast connections, and so extended toSC-PTM. The proposed cross-layer approach considers totally different aspects at physical layer (e.g., SINR and throughput),MAC layer (e.g., RRM, priorities and channel assignments), and flow-level (evolution of incoming and outcoming users) [152]. Some analytically tractable solutions ar derived, conjointly in closed kind where possible, and a proposal is formed, that varies the MCS per the users channel conditions.

6.5 Summary

Some works describe totally different aspects of SC-PTM [15], [16]. They principally specialise in physical layer aspects like signal interference, frequency employ schema, BSs locations, MIMO multiplexing and SE [15]. A comparison between PTM and MBSFN multicasting is analyzed for performance analysis. An effort is additionally created to extend the accuracy of the analysis, by taking into consideration many transmission aspects that contribute to a price operate designed for performance analysis functions [16]. These works gift conjointly correct numerical results through intensive simulations or ad-hoc tools. Lessons learned: Comparison between the 2 main approaches for multicasting in LTE systems, i.e., PTM and MBSFN, is one of the foremost fascinating problems and expresses the necessity to quantify the professionals and cons of every resolution. Accordingly, a awfully correct analysis, particularly at physical layer, of the 2 transmission schema is mandatory, that may be a terribly troublesome task because of the various standard-related aspects of each PTM and MBSFN. The physical layer of SC-PTM is analyzed with specific respect to MIMO and multiplexing techniques, power consumption and optimum choice of transmission parameters at physical layer [14]–[17]. The novel proposals specialise in enhancements in signal strength and rate, step-down of the ability consumption [14] and optimum alternative of MCS and CCs in specific application scenarios [17]. Lessons learned: Like MBSFN, conjointly for SC-PTM the physical layer aspects are of paramount importance to enhance the general quality of knowledge reception for QoS functions. within the case ofSC-PTM, since multicasting acts among the boundaries of one cell, the novel proposals ought to take into account signal interferences with adjacent cells sending constant service, particularly in an exceedingly context that doesn't need synchronization. The works regarding the mack layer of SC-PTM multicasting principally contend with programing and error management methods through feedbacks [15]. Proposals during this direction optimize the selection of the transmission mode [148],

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programing [19], and resource allocation . the most goal is to increase the strength of the packet transmission in associate degree erring channel to extend information turnout[19] and scale back the packet error likelihood . Lessons learned: The novel methods planned for SC-PTM at mack layer ensure the necessity to extend the strength of packet transmission, to avoid wasting energy and increase turnout. optimum solutions to those issues don't seem to be easy to succeed in conjointly in single-cell environments, particularly once multiple metrics ought to be put together optimized.A couple of works propose cross-layer optimizations for SC- PTM [11], [12]. during this respect, the novel strategies specialise in signalling procedures and resource management and management, in specific application scenarios like broadcasting of knowledge and television services. Lessons learned: Cross-layer methods are a awfully fascinating and a lot of complete approach, since they put together take into consideration totally different layers of the protocol stack, through theoretical [14] or test bed-based [11] analysis. nonetheless, this kind of approach is a lot of advanced to face, as a result of it ought to take into consideration each the various layers of the protocol stack and interfaces among layers. Table VII summarizes the most approaches for PTM transmission schema

VII. FURTHER INSIGHTS ON NETWORK CODING TECHNIQUES OPTIMIZATION ALGORITHM

Network secret writing techniques Network secret writing could be a terribly attention-grabbing technique that aims at increasing outturn by reducing the number of packet transmissions, at constant time increasing the number of data changed between source and destination nodes. With Old North State there's no would like of packet retransmissions and receiver feedbacks, thus saving information measure and power, and packet losses area unit reduced by properly secret writing packets additionally at intermediate nodes, instead of solely at the supply node. additionally security is multiplied, since the transmitted packets area unit mixtures of the first packets. For of these reasons, Old North State is that the right alternative in wireless networks eventualities, wherever the transmission is subject to signal errors and outturn limitations, and securing packets is of nice importance. it's been enforced at totally different layers of the protocol stack, to improve the transmission performance, particularly in terms of outturn and strength toward losses. In the specific LTE state of affairs, Old North State is often applied at raincoat layer. The key-concept of Old North Stateis to mix additional packets returning from totally different supply nodes into one packet (the coded packet) [13]. This task is performed each at supply node, by combining totally different generated packets, and/or at intermediate nodes, by combining along packets returning from totally different other nodes. In typical packet switched eventualities (like Internet), Old North State is assumed for transmissions over so-called erasure channels, wherever packets area unit either received while not errors, or don't seem to be received. In such scenarios, the foremost wide used Old North State techniques area unit variants of block-based codes for erasure channels, the most representative of that is that the Reed-Solomon secret writing technique. It consists of generating, at source side, variety of coded packets, say N, on top of the first variety of packets, say K. Packets area unit coded in such how that once the receiver has with success received any K of the N coded packets, the original K packets is recovered [12]. A code rate is additionally outlined, because the magnitude relation $K/N \leq$ one. it's obvious that this type of secret writing technique is effective just for little values of N and K, and for top code rates. This technique has evolved into another category of erasure correcting codes, the Fountain codes, where packets area unit coded in such how that the first K packets is with success decoded by receiving a (possibly slightly) higher variety of packets, that isn't determined a priori, however varies dynamically as the minimum variety of coded packets required to recover the first data. For this reason, Fountain codes area unit aforesaid to be “rateless”. B. improvement algorithms Several works propose algorithms for the improvement of various aspects of multicast transmission in LTE, starting from MCS choice and beam forming improvement at physical layer, to planning, subgrouping techniques, power and resource allocation, and superimposed video transmission. All the improvement algorithms area unitexploited normally to maximise, or minimize, AN objective perform with one or additional input variables, subject to some difference constraints. The affected improvement issues will continually be solved through the questionable thoroughgoing search (or direct search, or brute-force) schema. ESS algorithms find the worldwide answer to the matter, bytesting all the values of the input variable(s) so as to seek out the solution, however they will need preventative procedure efforts and execution times to seek out the answer, especially if the quantity of variables is high. So, they're typically not appropriate for period computations, and very usually approximated looking algorithms area unit required, that notice a suboptimal answer however with much less procedure effort [18]. totally different approaches area unit planned, that area unit classified within the following subsections as thoroughgoing

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search schema, Genetic algorithms, Standardized programming-based optimization techniques, Game metaphysical approaches, repetitive algorithms, and Heuristic methods.

1) Thoroughgoing search schema: As explained antecedently, ESS approaches guarantee the worldwide optimum solution, however at the expense of a large procedure price, that fairly often isn't possible in sensible scenarios. within the works [10], [14] examples is found of the applying of this approaches. The work [107] proposes a planning algorithmic program that organizes multicast users into subgroups, whereas the work [14] proposes totally different improvement algorithms that apportion resources to the various layers of a superimposed video for ascendible video transmission. an efficient technique is to perform constant ESS procedure, but on a reduced search area to cut back the procedure price, as testified by the works [8], [6], [1]. Specifically, in [2], [10] this approach is adopted in a very cluster formation algorithmic program with D2D links, to maximize the general system rate. In [8] the algorithmic program optimizes the placement of RSs to maximise the system outturn.

2) Genetic algorithms: Another category of improvement algorithms exploits a genetic approach, that can be synthesized into AN organic process methodology supported the "survival of the fitted" conception. In GAs, the place to begin is AN initial population, typically drawn by random strings of mounted or variable length. The people of the population area unit characterised by questionable fitness values, that area unit computed by suggests that of AN objective perform, to discriminate between "good" and "bad" people. Then, the best fitted people, representing the optimum answer at this step, area unit chosen for copy, and new, mutated people area unit generated from the chosen ones, by crossing them over. Then the process repeats, generating different people with an improved fitness, and once variety of iterations, the population converges towards the optimum.

3) Standardized programming-based improvement techniques: Some improvement techniques exploit a well outlined structure of the target perform, the input variables, and also the associated constraints. Depending on this, totally different types of programming issues area unit introduced. during this section, the programming techniques found within the analyzed literature are explained very well. the primary quite programming technique is that the whole number programming, wherever the input variables will assume solely whole number values.

4) Game metaphysical approaches: Some improvement issues found within the context of resource allocation strategies area unit solved by suggests that of game metaphysical talks approaches. Basically, they're supported a set of players, every of them characterised by a collection of actions and a perform distinctive the strategy of the player. every player is needed to own a minimum performance worth to enter the sport, called as “disagreement point”. samples of this approach area unit found in [104]–[106], wherever improvement algorithms are developed for methods of subgrouping and resource allocation.

5) Repetitive algorithms: Some improvement algorithms area unit solved through repetitive procedures that cannot be framed at intervals any of the approaches mentioned within the previous subsections. These procedures are formally enforced by suggests that of nested cycles that perform a hunt over all the input variables, and update {the worth the worth}of the target perform whenever a replacement optimum value (maximum or minimum) is found. The works[12] exploit such algorithms. planning algorithms area unit mentioned in [20], [11]. In [4] algorithms are planned for grouping UEsin clusters. improvement algorithms area unit planned in [5] for combined Unicast/Multicast planning. The algorithms bestowed in aim at finding the best MCS that optimizes a predefined metric through the SE analysis.

The work [7] proposes AN algorithm for optimum resource allocation for superimposed video transmission. an influence improvement algorithmic program for multicasting of video streams is bestowed in [8]. improvement algorithms for subgrouping methods are developed in [10]. The Analysis developed in [9] contains an algorithmic program that finds the minimum MCS satisfying atarget SE. The improvement algorithmic program planned in [12] assigns the simplest MCS to every read of a multi-view video stream, in order that the information measure consumption is decreased .

6) Heuristic strategies: Heuristic approaches area unit usually accustomed notice AN approximate answer to AN optimization downside, sacrificing the preciseness and correctness of the optimum answer found in favour of a reduced procedure complexness and a quicker execution time of the algorithmic program. Heuristic strategies area unit introduced as a result of the optimum answer to the first downside is extremely exhausting to seek out in a very affordable time; the approximations introduced usually don't explore all the search areaand/or explore solely some discretional solutions, usually the foremost doubtlessones, excluding the others. As a consequence, the approximations

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introduced don't exactly describe the matter to be optimized and, consequently, the overall optimum answer can likely not be found. Rather, a suboptimal answer (the socalled “local optimum") is found, that's the results of the algorithmic program within the reduced search area that verifies the constraints. Please note that some categories of optimizations algorithms delineate within the previous subsections, i.e., genetic algorithms, game metaphysical approaches, and repetitive algorithms, can be considered as explicit categories of heuristic algorithms, with well outlined resolution procedures.

VIII. CHALLENGES AND FUTURE RESEARCH DIRECTIONS

LTE and its evolutions, based on newer releases of the 3GPP standard, is a very complex system, because of its ambitious goals, just to cite some of them: high throughput, mitigation of interference inthe wireless channel, spectrum and resource optimization, scheduling and retransmission, power control, energy saving, device cooperation, security, etc [14]. This reflects also on multicasting and broadcasting of services, where there are several issues that need to be addressed, and that determine the possible directions of future research on this subject. The description that follows does not pretend to be exhaustive, but rather to give a comprehensive idea of the most important issues on LTE multicasting that still need to be developed in the opinion of the authors. A first important issue can be found in the absence of feedbacks and retransmissions in MBMS, that paves the way to the study and implementation of FEC schema and coding techniques. Research efforts could be directed atreducing as much as possible the more critical issues related to the coding procedures, i.e., the bandwidth overhead due to the error protection procedures and the delay needed to recover from lost packets; all this, at the same time guaranteeing an acceptable degree of robustness towards packet loss for QoS/QoE purposes. A first solution to this issue can be a strategy for the dynamic selection of the most suitable coding technique (i.e., the number of redundant packets to be generated to obtain a given packet error rate), depending on the network conditions. Another possible solution is to combine FEC schema with cooperation/relaying techniques and/or other types of network architectures like P2P and mesh networks, to reduce the number of coded packets transmitted at source side at the same time keeping the same number of redundant packets received to save network resources. Also the utilization of MIMO techniques in combination with error correction schema could be useful to improve the system performance. Cooperative networks are another interesting research theme for LTE multicasting, as testified by the works found in literature. Relay nodes can be of great help to offload the traffic at BSs, increase throughput and coverage, and reduce interference. Future research directions could consider more accurate and sophisticated relaying schema, where BSs can schedule multicast data to relay nodes, to achieve better coordination and reduced interference among D2D nodes. The joint use of MIMO and scheduling techniques is another interesting research topic in the cooperative network scenario, because it can intuitively increase the system performance, even if it complicates the modeling, the analysis and the implementation of the MBMS scheme. At physical layer, MIMO is a value-added feature in MBMS, because it increases the data rate and reduces interferences through beamforming techniques. Issues related to this topic are the choice of the optimal antenna selection and the shape of beamformers signals. In this context, the optimal choice of the number and position of the antennas is crucial to exploit at best MIMO features. It would be interesting to extend the existing studies to more complicated scenarios, where different services are multicasted to different multicast groups, at the same time keeping a manageable computational complexity of the proposed optimization algorithms. The MBMS architecture, the main topic of works on LTE multicasting, has been discussed in many works. The analysis of the main logical components of the MBMS architecture has been considered in some works, also evaluating the possibility of exploiting this architecture in different application scenarios, like TV broadcasting, Intelligent Transportation Systems, vehicular networks, etc. Nevertheless, there are some interesting research possibilities in the joint analysis of the mutual interaction among all the components of the MBMS architecture, to improve delivery of multicast services. A detailed analysis of some specific aspects like end-to-end delay and users mobility, that are critical in some emergency scenarios but not widely treated in the recent literature, would be useful in this context. Also theoretical models on these aspects have not been developed but can be of interest to analyze the behaviour of some performance metrics. The coexistence of different types of networks architectures including MBMS has been discussed in the recent literature, but research on this topic could focus on a more detailed study of coordination capabilities among network architectures, through a cross-layer cooperation among the different layers of the protocol stacks. To this extent, control plane procedures assume a high

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importance, even if this aspect has been almost neglected in the recent literature. Concurrently, another aspect to take into account in this research field is how toset- up, improve, or modify, the interface specifications of the networks involved in the hybrid architecture, to allow a better adaptation among different protocols of the stacks. Novel hybrid architectures could also be considered, to mitigate some inefficiencies of the wireless transmission.

Just to give a possible research direction on this topic, the spectrum scarcity is a factual reality, and hybrid networks that consider the use of CRNs together with MBMS would be of help to this effect. Another interesting research direction is the analysis of the cost of the coexistence among hybrid architectures, in terms of communication metrics (delay, throughput etc.), implementation and interfacing of the different architectures. This aspect has not been properly taken into account in the surveyed literature.

Scheduling is a widely treated topic in the recent literature. The most critical issue in this context are the optimization algorithms adopted, that aim at finding the best solution in a multidimensional search space. Furthermore, the large majority of the proposed solutions perform scheduling in the time domain. Much less efforts have been made to schedulers that act in the frequency domain, which can be instead an interesting research topic due to the intrinsic frequency-selective nature of the channel. An even more interesting effort can be made by developing schedulers that act in both time and frequency domains, to further increase (but complicate) the optimization process of resource allocation. Coordination among cells to increase SINR and data rate is an open issue for MBSFN. This aspect is important because it can increase throughput at cell edge, the network coverage, and the suppression of interference among adjacent cells in the MBSFN area. All these aspects require further research efforts, translating into strategies and algorithms aiming to reach this goal, at the same time taking into account all the control plane procedures that can guarantee the cell synchronization in the MBSFN area. In this context, research should also move towards an efficient selection of the BSs that can contribute to the creation of a MBSFN area, depending on their mutual position, distance, and transmission power, especially for coverage maximization and interference minimization purposes; to the best of the authors knowledge, this aspect has not been properly taken into account in the works on LTE multicasting. Secure multicast communication is another research issue in LTE multicast transmission. The main focus of this topic should be the guarantee of confidentiality among authenticated users in multicast group. Few efforts have been made in this direction; so, future studies should pointon advanced authorization and encryption mechanisms for multicasting of reserved data. Another interesting research direction could consider anomaly detection algorithms that prevent from Denial of Service (DoS) attacks and unauthorized access to multicast groups. There is a strong need to use sophisticated simulation/emulation tools that take into account as much as possible all the layers of the protocol stack and their mutual interactions (through cross-layer analysis), to increase the simulation accuracy. A research effort towards this direction could be very appreciated to provide more realistic results in different practical scenarios. To this end, the tools developed should take into account several aspects, i.e., the transmission of different services in a MBSFN area, users mobility and service continuity, and the terminals energy consumption, which have been almost neglected in all the works on this topic. Higher layers parameters should also be considered as simulation outputs, to assess the quality of the received data in application scenarios like video multicasting. Optimization algorithms have been widely used in LTE multicasting to find the solution to several problems, especially in the context of novel scheduling techniques, SE optimization, and subgroup formation strategies. The main issue is that the problems very often require the optimization of more variables that jointly contribute to the optimization function, and the ESS schema used to find the optimal solution can be computationally very expensive. Research directions in this regard aim to find the approximations in the optimization algorithms that allow the best trade-off between computational complexity and the closeness of the suboptimal solution to the globally optimal one. This task is not trivial because the accuracy of the search algorithm chosen depends on several factors, i.e., the number of variables, the structure of the optimization function, the limits of the search space (if any), etc. and the low complexity of the algorithm is a key-feature to find the solution inreal-time, which is a desirable property in practical scenarios. Transmission of compressed video, including SVC, is the most widely used application scenario for service multicasting in LTE. Novel proposals and algorithms should beevaluated explicitly in this context. Even if some research efforts have already been made in this direction, performance of video multicast in MBMS networks should be evaluated by considering more video quality metrics, like Structural Similarity Index Metric (SSIM), the Video Quality Metric (VQM), or the Perceptual Evaluation of Video Quality (PEVQ), that are more difficult to evaluate and require more computational efforts than the mostly used PSNR, but provide a more

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exhaustive evaluation of the perceived video quality. As regards SC-PTM, much less research effort has been spent if compared to MBSFN, but almost all the issues addressed above remain still valid also for single cell multicasting. In addition, a critical issue in this context is an analysis of the inter-cell interference, that worsens the received multicast signal and the overall transmission performance. Novel error protection and retransmission strategies and detailed analytical models of transmission aspects that take into account this further complication are surely of particular interest in this research field.

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