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The Challenge: From MPEG Intellectual Property Rights Ontologies to Smart Contracts and Blockchains

The Moving Picture Experts Group (MPEG) is an International Organization for Standardization/International Electrotechnical Commission (ISO/IEC) working group that develops media coding standards. These standards include a set of ontologies for the codification of intellectual property rights (IPR) information related to media. The Media Value Chain Ontology (MVCO) facilitates rights tracking for fair, timely, and transparent payment of royalties by capturing user roles and their permissible actions on a particular IP entity. The Audio Value Chain Ontology (AVCO) extends MVCO functionality related to the description of IP entities in the audio domain, e.g., multitrack audio and time segments. The Media Contract Ontology (MCO) facilitates the conversion of narrative contracts to digital ones. Furthermore, the axioms in these ontologies can drive the execution of rights-related workflows in controlled environments, e.g., blockchains, where transparency and interoperability is favored toward fair trade of music and media. Thus, the aim of this article is to create awareness of the MPEG IPR ontologies developed in the last few years and the work currently taking place addressing the challenge identified toward the execution of such ontologies as smart contracts on blockchain environments.

Background

Motivation

Copyright legislation has continuously evolved with the aim of reviving the music industry in terms of fair and increased revenues returned to artists and rights holders, improved multiterritory licensing, timely payments, and overall, more transparency, e.g., the United States Music Modernization Act [1] and the European Union's Copyright Directive Reform [2]. Meanwhile, several key artists and musicians have turned their hopes for resolving these issues to technology and, in particular, blockchain [3], [4].

Blockchain emerged in 2008 as the technology that underpins bitcoin. It operates as a shared ledger that continuously records transactions or information. Its database structure, where there is a timestamp on each entry and information linking it to previous blocks, makes it not only transparent but exceptionally difficult to tamper with.

Initiatives investigating blockchain have been launched around the world. In the United States, the Open Music Initiative (OMI) [3] has been launched by the Berklee Institute for Creative Entrepreneurship, harnessing the expertise of the Massachusetts Institute of Technology Media Lab, in decentralized platforms, whose mission is to promote and advance the development of open source standards and innovation related to music and to help ensure proper compensation for all creators, performers, and rights holders of music. OMI's focus is 1) on new works, rather than the vast legacy music catalog, with the aim that the same principles can be applied to legacy music retrospectively; and 2) on achieving interoperability among infrastructures, databases, and systems so they can be accessed, shared, and exchanged by all stakeholders.

In Europe, one of blockchain's evangelists is the Grammy-award-winning U.K. singer, songwriter and producer Imogen Heap. She has launched a blockchain project, Mycelia [4]. Although still in its early stages, she intends Mycelia to be an entire ecosystem that uses blockchain as a way to shake up the music industry. Mycelia's mission is to

1) empower a fair, sustainable, and vibrant music industry ecosystem involving all online music interaction services
2) unlock the huge potential for creators and their music-related metadata so an entirely new commercial marketplace may flourish
3) ensure that all involved are paid and acknowledged fully
4) set commercial, ethical, and technical standards to exponentially increase innovation for the music services of the future
5) connect the dots with all those involved in this shift from our current outdated music industry models while exploring new technological solutions to enliven and improve the music ecosystem.

Such missions can be accomplished thanks to MPEG IPR ontologies, which can be used by music and media value chain stakeholders to share and exchange all metadata and contractual information connected to creative works, in a standardized and therefore interoperable way, leading to transparent payment of royalties and reduced time spent searching for the right data. The latter is due to inference and reasoning capabilities inherently associated with ontologies. That is, knowledge and data can be derived by evidence (facts) and logic based on rich semantic copyright models expressed by MPEG IPR ontologies. In this way, the data derived are unambiguously interpretable, facilitating efficient processing in business-to-consumer and business-to-business (B2B) music and media value chains.

However, while enthusiasm is growing for blockchain, it is likely to be

Digital Object Identifier 10.1109/MSP.2019.2955207
Date of current version: 26 February 2020

several years before we see it rolled out in a wide-scale, mainstream capacity. Blockchain enables value to be transferred over the Internet. For contractual music and media asset trading, smart contracts can be used to encode the terms and conditions of a contract. They validate contractual agreements between stakeholders before a blockchain value transfer is enabled [5]. In other words, smart contracts, implemented via software, could allow music and media royalties to be administered almost instantaneously and manage usage allowances and restrictions. Rather than passing through intermediaries, revenue from a stream or download could be distributed automatically to rights holders, according to agreed terms and conditions (e.g., splits), as soon as an asset is downloaded or streamed [6], [7].

In the last few years, MPEG has developed a number of standardized ontologies catering to the needs of the music and media industry with respect to codification of IPR information toward the fair trade of music and media.

That is, while various smart-contract solutions abound, it is likely that the technology will really only take off once there is a clear consensus in business about which standards will prevail [8]. So the challenge that naturally arises is as follows. How can MPEG IPR standardized ontologies be converted to smart contracts that can be executed on existing blockchain environments, thus enriching blockchain environments with inference and reasoning capabilities inherently associated with ontologies? Note that this process will increase trust among music and media value chain stakeholders for sharing data in the ecosystem since the data will be cryptographically secured and verified by a blockchain.

From the other side, while plenty of research literature deals with semantic-level interoperability of ontologies (linking different ontologies) and protocol-level interoperability of blockchains (transferring verified data from one to another), the interoperability gap between them has not yet been sufficiently bridged [9]. Toward this direction, MPEG is not going to develop any blockchain-based technology or any new language for smart contracts. However, in the last few years MPEG has developed MPEG IPR ontologies, which facilitate the conversion of narrative contracts to digital ones. Thus, MPEG's aim is to further develop the means (e.g., protocols and application programming interfaces) for converting MPEG IPR ontologies to smart contracts executable on existing blockchain environments. In that way, MPEG is going to close the interoperability gap between MPEG IPR ontologies (and consequently the Semantic Web) and blockchains.

Last but not least, a standards-based fair and sustainable trade of music and media ecosystem is envisaged [10] based on widely deployed MPEG technologies (e.g., audiovisual codecs, file formats, and streaming protocols) [11], including emerging MPEG IPR ontologies executed as smart contracts on blockchain environments.

Issuing body

MPEG, officially known as *ISO/IEC JTC1/SC29/WG11*, is a working group of Standardization Subcommittee 29 of the Joint Technical Committee 1 of the ISO and the IEC, that develops and facilitates international standards within the field of audio, picture, multimedia, and hypermedia information coding.

In the last few years, MPEG has developed a number of standardized ontologies catering to the needs of the music and media industry with respect to codification of IPR information toward the fair trade of music and media. These MPEG IPR ontologies have been developed using the World Wide Web Consortium's (W3C's) Resource Description Framework (RDF), under the MPEG-21 Multimedia Framework (ISO/IEC 21000) family of standards, and include *MVCO* (ISO/IEC 21000, Part 19), its extension with respect to multitrack audio and time segments, known as *AVCO* (ISO/IEC 21000, Part 19/Amendment 1) and *MCO* (ISO/IEC 21000, Part 21). With respect to the latter, an equivalent standard has also been developed using W3C's XML, known as *Contract Expression Language* (ISO/IEC 21000, Part 20). Next, the aforementioned MPEG IPR ontologies are described. Terms in italics are further defined in the standards given in "Resources."

Technology

The MVCO

Main entities

The MVCO [12] is an ontology that formalizes the media value chain. The MVCO was designed to satisfy a number of requirements, which in turn led to defining three entities of top importance: *IP entities*, as they are transformed along their life cycle, relevant *actions* that can be performed on such entities, and types of *users* whose actions are rights, obligations, or something else foreseen by IP law.

IP entities are objects (e.g., work, manifestation, instance, product) in the media value chain, subject to protection by copyright law. The very first entity in the chain is the abstract creation, the *work*, which is the result of any intellectual endeavor with enough creativity. Works are pure, abstract entities with no material incarnation whatsoever. Derivative works are special types of works derived from an existing work. Works are fixated into physical *manifestations*, which are the very first incarnation of works. Manifestations can be *instanced* and *copied*, or they can be transformed into commercial *products*. Whereas the logical schema of IP entities resembles the Functional Requirements for Bibliographic Records (FRBR) chain [13], the source is somewhat different: the MVCO, catering to the needs of music and media stakeholders, codifies the IP entities mentioned by copyright legislation (as defined by worldwide treaties, such as the Berne Convention), whereas the FRBR is inspired by the needs of librarians.

A *user* is defined as an individual or organization acting in the media value chain. The types of roles a user could undertake revolve around the IP entities, e.g., a *creator* is defined as the user who creates a work; an *adaptor* is the user who adapts a work to produce an adaptation. These roles or very similar ones are also acknowledged by copyright legislation. Other roles include producer, distributor, and, finally, the end user.

The types of actions that can be performed also revolve around the IP entities. *Create work* is the action whose result is a new work, *produce* is the action whose result is a product, and so forth. In addition, some other actions do not produce any new IP entity. Such actions include a public communication or an end-user action (e.g., play and print), but they are legal concepts with explicit mentions and provisions in copyright legislation.

The relationship between a user and a particular IP entity type (e.g., work, adaptation, product, copy) is specified through the concept of *role*. The actions that a user performs on a given IP entity determine the role of that user with respect to the IP entity in question. Users get roles (e.g., creator, adaptor, producer, end user) that attribute them rights over actions (e.g., create work, make adaptation, produce, distribute, synchronize) that can be exercised on specific IP entities. Any given user may undertake any number of roles within a given value chain. Figure 1 illustrates these relationships among actions, users, and IP entities.

Authorization model

The MVCO, by defining the relationships between users, actions, and IP entities, serves well to depict a static picture of the IP information. However, in real life, rights are transferable and the MVCO needed to support this dynamic nature of rights.

The transfer of rights are authorized by signatures on agreements or contracts that grant *permissions.* A permission relates an IP entity to a right in transit between the original rights owner and the new rights owner. Permissions have an intrinsic dynamic nature: they are granted, invoked, and revoked. Instances of a user class will probably be actual companies or persons; instances of works will be actual works. However, instances of permissions are far more interesting because they could refer either to the past or the future.

That is, an instance permission (e.g., Alice's permission to play a song) would be related to both an end-user instance (e.g., Alice) and an action instance (e.g., play a song). However, what is the interpretation of an action instance? It might be an action effectively executed in the past (e.g., Alice played a song), but it might also be an action to be performed in the future, as a mere possibility (e.g., Alice can play a song). This is commonly referred in the literature as *event factuality* and suggests that action instances can be marked as executed acts or as possible acts.

Permissions can also be granted conditionally, that is, subject to certain conditions (*facts*). Facts can be seen as propositions with an alethic (e.g., true or false) value. These propositions can be combined with logical operators (e.g., conjunction and disjunction) to create more complex conditions. The evaluation of conditions against a certain context would determine whether a permission would actually be granted or not. In such a context, permissions can also be expressed as prohibitions (negation of a permission) and obligations (the prohibition of not doing something).

Finally, the MVCO supports to some extent the so-called *copyright exceptions*, a notion present in IP law to enable the reasonable use of copyrighted assets in certain cases. For example, complete quotes are allowed for scientific purposes, and parody is also permitted. The MVCO provides mechanisms for specifying such copyright exceptions, although the exceptions themselves are not specified.

The AVCO

The AVCO facilitates transparent IPR management even when content reuse is involved. This relates in particular to widespread adoption of interactive music services (remixing, karaoke, and collaborative music creation) enabled by MPEG-A: Interactive Music Application Format [14], also known as *Stem* [15], which raises the issue of rights monitoring when reuse of audio IP entities is involved, such as tracks or even segments of tracks in new derivative works.

AVCO addresses this issue by extending MVCO functionality related to the description of composite IP entities in the audio domain, whereby the components of a given IP entity can be located in time and, in the case of multitrack audio, in association with specific tracks. To do so, AVCO introduces, as shown in Figure 2, the concepts of

1) *timeline* [16]: a linear and coherent piece of time in relation to time-based IP entities, e.g., a vocal track can be associated with such a timeline
2) *interval*: a temporal entity defined by a start and end points on a given timeline, e.g., the chorus interval of a vocal track
3) *segment*: a slice of an IP entity with boundaries defined by the interval's start and end points, e.g., the chorus interval's IP entity
4) *track*: a single track of a multitrack audio IP entity, e.g., the vocal track's IP entity.

The introduction of an additional *reuse* action enables querying and granting permissions for the reuse of existing IP entities to create new derivative composite IP entities.

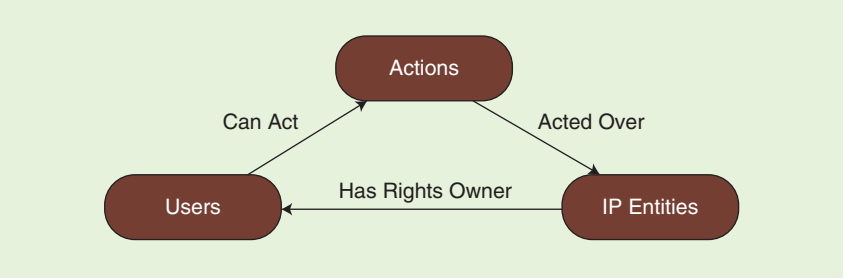

FIGURE 1. MVCO-defined relationships among actions, users, and IP entities.

Relationships for IP entity segments and tracks

The AVCO-defined classes and relationships are illustrated in Figure 3. Since IP entities in the audio domain constitute timed media, a timeline can be associated with them. That is, an IP entity through the property *interval* is linked to an interval (Interval class instance), which in turn, through the property *onTimeLine* is associated with a timeline. The property interval is also handy to be expressed that a segment exists within a specified interval on a timeline.

A segment is usually in a part-of relationship with an existing IP entity linked to it through the *hasSegment* property. However, a segment may also contain an IP entity different than the existing (reused) one. In either case, since a segment is subsumed by the *IPEntity* class, it is an IP entity with its own value chain resolving to its rights holders.

In the case of multitrack audio resources, an IP entity is related to a specific track with the *hasTrack* property. To be expressed that a segment exists on a certain track, it is linked to the respective track using the *onTrack* property.

In that way, reused IP entities may exist in specified segments of existing IP entities and, in the case of multitrack audio IP entities, on specified tracks.

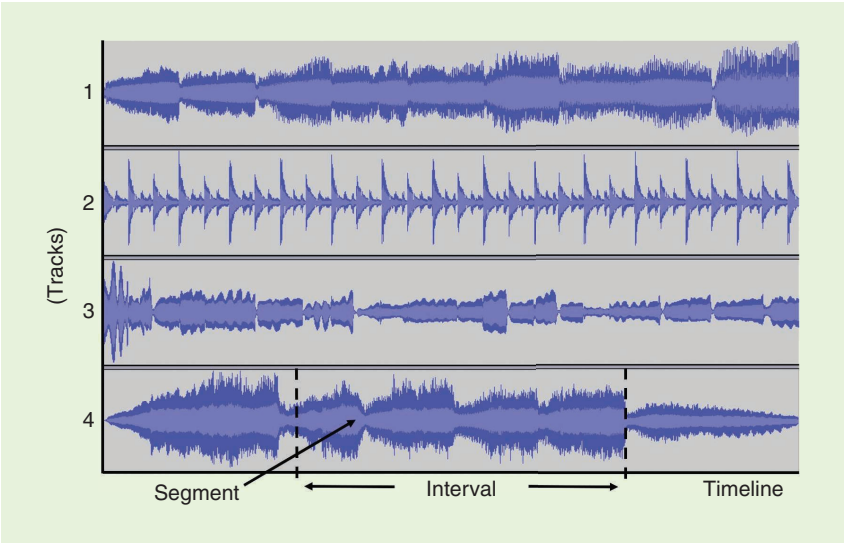

FIGURE 2. Recordings representing visualized multitrack audio. A segment exists within an interval on a timeline.

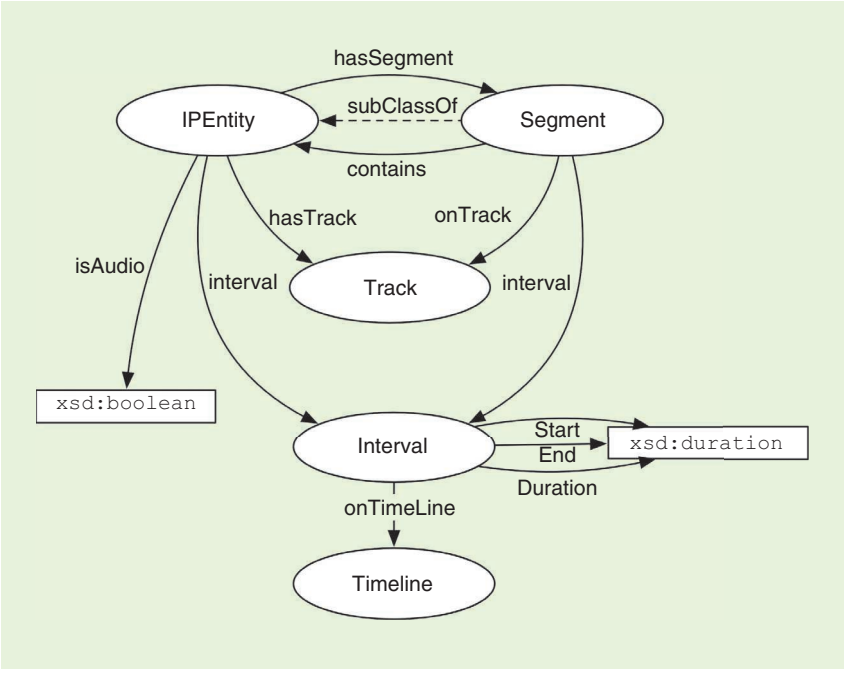

FIGURE 3. ACVO-defined classes and relationships for the representation of IP entities that contain other existing IP entities. Segments can also be associated with individual tracks of a multitrack audio IP entity.

The MCO

The MCO [17] facilitates the conversion of narrative contracts to digital ones and permits the creation of new contracts in machine-readable electronic formats. It consists of a core model (mco-core) and two extensions. The core model, as shown in Figure 4, builds on top of MVCO generic deontic statements (encompassing the concepts of permission, prohibition, and obligation) by providing the elements for modeling the basic structure of media contracts (e.g., contract and parties identification and relationships with other contracts). The two extensions are 1) Exploitation of Intellectual Property Rights and 2) Payments and Notifications.

Exploitation of IPR

The extension for the exploitation of IPR (mco-ipre) provides the means to express the rights for exploiting media content, as is typical among audiovisual production companies and broadcasters. In such a context, the most commonly used rights for media exploitation are those for *public performance* (e.g., where the public is present), *fixation* (e.g., when a performance is recorded on a tangible medium), and *communication to the public* (e.g., where the public is reached by means of a communication technology). As in narrative contracts, these exploitation rights might be associated with a wide set of conditions (*facts*; e.g., number of broadcast transmissions, time periods, territories, languages, exclusivity, royalty percentages), *modalities* (e.g., linear/broadcast, nonlinear/broadband),

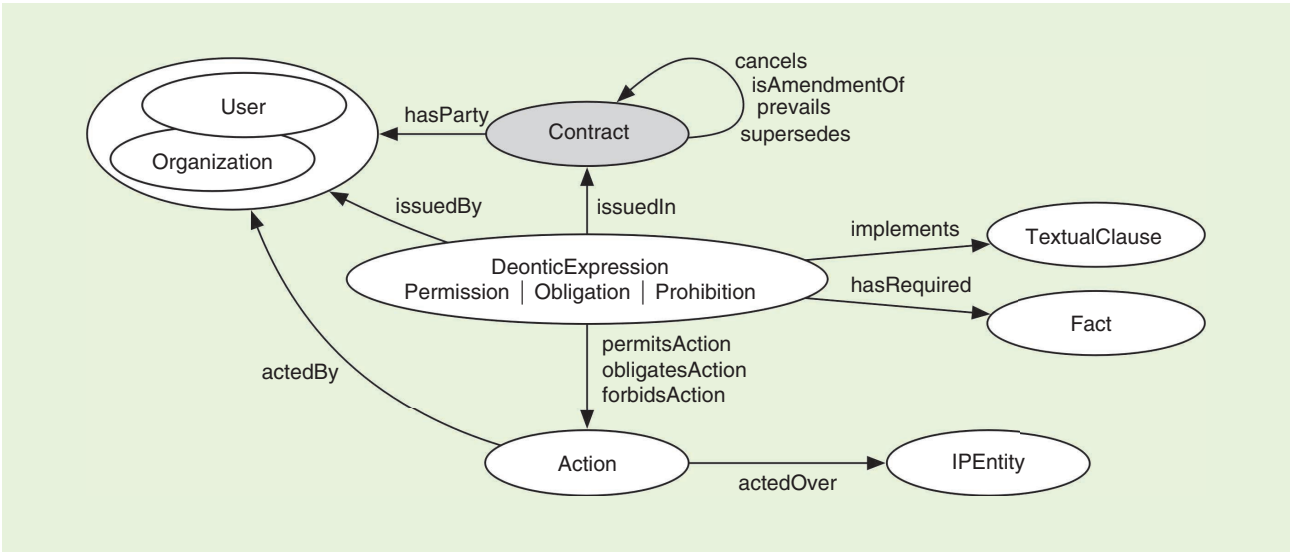

FIGURE 4. The main elements of the MCO model.

and *access policies* (e.g., free of charge, subscription, pay per view).

In the main model (mco-core), actions are permitted when the required conditions are met (e.g., the required facts are true). However, with this extension on exploitation of IPR (mco-ipre), dependencies between different actions can also be specified. That is, the occurrence of an action, such as the exploitation of a right, can trigger a condition for another action. This mechanism allows the specification of complex rights' dependencies, such as, for instance, in the so-called catch-up TV service (a combination of both linear/broadcast and nonlinear/broadband communication to the public) offered by a number of broadcasters. As an example, consider a broadcasting operator who has acquired the right from a production company to *broadcast* a TV episode. The broadcasting operator has also acquired the right to make the TV episode available on demand from its website to its subscribers via *broadband* access but only after the TV episode has been broadcast. In this case, the latter right (communication to the public via broadband) is dependent upon the use of the former communication to the public via broadcast.

Payments and notifications

The extension for payments and notifications (mco-pane) provides means to define specific obligations for completing a media contract scenario. Both payments and notifications are typically obligated actions that can either be triggered by (as a consequence of) rights exploitation actions or required as a precondition to rights exploitation actions.

Eventually, the MCO can be used for the conversion of narrative media contracts to digital ones and vice versa. Such an MCO-based rights management system has been built and used by Radiotelevisione Italiana to store, access, and modify information on media rights purchased and used across its departments involved in activities ranging from media production to broadcast scheduling, improving the efficiency of media operations. Furthermore, interorganizational (B2B) rights management interoperability could be achieved by the deployment of MCO open standards by other media production companies and broadcasting operators.

Usage example

The MPEG IPR ontologies can be used as data models, e.g., knowledge graphs, for representing media rights. That is, actual users, media assets, and rights can be represented in RDF, instantiating MCO/MVCO/AVCO classes. The next RDF statements declare a work identified by an International Standard Musical Work Code with exploitation rights assigned to a certain PartyA:

```
:myWork a mvco:Work;
  mvco:hasRightsOwner
  "PartyA";
  :myWork  owl:sameAs
  "T-034.524.680-C";
```

The exploitation rights on this work may be described in a contract represented using the MCO. A basic MCO contract follows. This allows the communication to the public right of the aforementioned work to be transferred from PartyA to PartyB:

```
:a Contract a mco-core:
Contract;
  mco-core:hasParty
  "PartyA", "PartyB";
[] a mvco:Permission;
  mvco:permitsAction mco-
  ipre:CommunicationTo
  ThePublic;
  mco-core:issuedIn:
  aContract;
  mco-core:actedBy "PartyB";
```

In this usage example, the joint use of terms defined in the mvco ontology (such as mvco:Permission), in mco-core (such as mco-core:Contract), and in mco-ipre (such as the communication to the public) has been shown. In practice, contracts will contain a number of restrictions and obligations (such as payments).

Further technical developments

MPEG IPR ontologies can be used by music and media value chain stakeholders to share and exchange in an

Resources

Standards

- *Information Technology—Multimedia Framework (MPEG-21), Part 19: Media Value Chain Ontology,* Standard ISO/IEC 21000-19, June 2010.
- *Information Technology—Multimedia Framework (MPEG-21), Part 8: Reference software/AMD2 Reference Software for Media Value Chain Ontology,* Standard ISO/IEC 21000-8/AMD2, Nov. 2011.
- *Information Technology—Multimedia Framework (MPEG-21), Part 19: Media Value Chain Ontology/AMD1 Extensions on Time-Segments and Multi-Track Audio,* Standard ISO/IEC 21000-19:2010/AMD1, June 2018.
- *Information Technology—Multimedia Framework (MPEG-21), Part 8: Reference Software/AMD4 Media Value Chain Ontology Extensions on Time-Segments and Multi-Track Audio,* Standard ISO/IEC 21000-8:2008/AMD4, Oct. 2018.
- *Information Technology—Multimedia Framework (MPEG-21), Part 21: Media Contract Ontology,* Standard ISO/IEC 21000-21 (2nd ed.), May 2017.
- *Information Technology—Multimedia Framework (MPEG-21), Part 20: Contract Expression Language,* Standard ISO/IEC 21000-20 (2nd ed.), Dec. 2016.

Software

- Media Value Chain Ontology: https://tinyurl.com/y6tsr9as.
- Audio Value Chain Ontology: https://standards.iso.org/iso-iec/21000/-8/ed-2/en/amd/4. (Note: Source code files provided replace the corresponding MVCO ones.)
- Media Contract Ontology: https://standards.iso.org/iso-iec/21000/-21/ed-2.

interoperable way all metadata and contractual information connected to creative works, leading to transparent payment of royalties and reduced time spent searching for the right data.

Such MPEG IPR ontology standards should convince music and media industry stakeholders to accept technology developments catering to the needs of music and media rights transparency built upon open standards. Related information can be found in "Resources."

Furthermore, an MPEG ad hoc group, known as *MPEG-21 Contracts to Smart Contracts*, has recently been established to investigate and develop hooks (e.g., protocols and application programming interfaces) for converting MPEG IPR ontologies to smart contracts executable on existing blockchain environments, thus further increasing trust among music and media value chain stakeholders for sharing data in the ecosystem. In that way, the group is going to also bridge the interoperability gap between MPEG IPR ontologies (and consequently the Semantic Web) and blockchains. Though the MPEG ad hoc group is in its infancy, it has attracted a significant number of industrial and academic experts from both the semantic and the blockchain communities committed to work on the identified challenge. The work is in an exploratory phase and a publishable working draft is expected soon. Such developments toward a *semantic music and media blockchain* have the potential to unlock both the Semantic Web and the creative economy.

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