Public Safety Radios Need to Pool Spectrum

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Abstract - The Dynamic Spectrum Access (DSA) research and improvement network is maturing technology so one can permit radios to share RF spectrum plenty more intensively. Adoption of DSA technologies through the general public protection community can better align systems with the future of wi-fi services extra usually and can make a contribution to creating next era public protection radio structures more strong, capable, and flexible.[1]

A essential first step closer to a DSA-enabled destiny is to reform spectrum control that allows you to create spectrum pools that DSA-enabled devices including Cognitive Radios (CRs) may additionally make use of beneath the manipulate of extra dynamically bendy and adaptive prioritization rules than is possible with legacy era[3]. Appropriate reform will enable spectrum portability, facilitating the decoupling of spectrum rights from the supply of infrastructure.[5][2]

It examines the monetary, policy, and market demanding situations of allowing spectrum pooling and portability for public safety radios.[1][4][5]

Key Words: Dynamic Spectrum Access (DSA), Cognitive Radios.

I. INTRODUCTION

Dynamic Spectrum Access (DSA) technology, which include Cognitive Radio (CR) technology, are in improvement for the subsequent era of industrial, army, business and public safety networks. These technology maintain the promise of delivering extra bendy and adaptive radio architectures, able to sharing the RF spectrum a great deal extra intensively than is possible with today's currently deployed technology[4]. The cutting-edge panorama of wi-fi networking displays the legacy of a international premised on static community architectures and spectrum allocations. In this world, public safety networks have traditionally been designed to meet capacity and reliability "requirements" that are based on consumer requirements at the "worst case" degree – this is the potential and reliability vital all through an emergency or disaster[5]. It is not assumed that the community will continually want these degrees of ability and reliability throughout "everyday" operations[9]. But it's miles assumed that the network have to continually have these stages of potential and reliability available while wanted. Such worst- case planning implies that giant spectrum and device assets want to be "stockpiled" and stay unused most of the time. This creates great artificial spectrum shortage, especially in the public safety bands, which are small allocations fragmented throughout more than one bands and lots of machine proprietors.[3][11]

The wireless international is converting. The desires for wireless systems of every kind, and for public safety systems in particular, have significantly accelerated. This increases the expenses andcollective infeasibility of persevering with worst-case making plans and the wasteful allocation of assets it implies.[2] The radio future, of necessity, will require moving to greater DSA-friendly modes of spectrum usage. Besides being inevitable, the transition to DSA will provide many substantial blessings for the public safety community and wireless customers extra generally. [12][7]

These advantages will consist of higher assignment responsiveness, extended talents, and in the long run, decrease fees. However, getting to this destiny may even entail overcoming important challenges[8][7]. A range of complementary improvements are required. These consist of similarly technical developments, public coverage reform, and converting enterprise and stop-consumer attitudes. While further technical research and product development is definitely wanted, our focus right here is at the policy and enterprise practice challenges of developing DSA technologies to be used by means of public safety structures[9].

II. CHANGING ENVIRONMENT FOR PUBLIC SAFETY RADIOS

While the appropriate form of the radio future may be tough to discern, certain key factors seem positive. The future radio surroundings will encompass hundreds extra wi-fi of a wide variety, greater demand for mobility and portability and more heterogeneous wi-fi networks[10][3]. These future developments may have concrete implications for radio community format, consisting of the want for extra broadband ability, allowing more dynamic and bendy offerings and spectrum sharing.[5]

A. Policy Based Radio

Cognitive radio (CR) captures the flavor of these advances: a CR is capable of sensing its local radio environment and negotiating modifications to its "waveform" (modulation scheme, power-level, or frequency/channel access behavior) in real-time with other CRs, subject to "policy constraints" (e.g., that may limit the range of waveforms

allowed). The policy constraints are enforced by the radio's policy engine. Policies may include authorization to transmit in specific locations and frequencies at specific times, or may include access protocol constraints (e.g., listen-before-talk)[7]. These policies may be static and hard-coded into the radio, downloaded from a database, or may be dynamic and subject to updating in real- time in communication with a network operator or other CRs. DSA/CR devices typically require location awareness capability in order to support the policy engine and because interference is a local phenomenon occurring at a receiver's location[11]. Finally, CRs are inherently multi-band radios, allowing the radio to transmit or receive in a wider range of frequencies than might be used in any specific communication environment. This allows CRs to opportunisticallymakeuse of unused spectrum and facilitates their interoperability with legacy radio systems.

While significant technical work remains to be done in academic research and commercial product development laboratories to field a commercially viable CR, prototypes already exist and many aspects of the technology are already embedded and working at scale in commercial systems. In this paper, we do not focus on the technical developments that still must be made, but rather on the policy innovations that are required to make commercialization viable.[9][8]

B. Next Generation Public Safety radios need to embrace DSA

The equal forces which can be shaping the destiny for business wi-fi follow with even more potent force to public safety wi-fi structures.[12]

First, public safety first-responders are more likely than most other users of ICT to require mobile, wireless access. In many first-responder eventualities, the most effective choice is wireless.

Second, first-responders who are dealing with lifestyles-and-demise conditions are perceived commonly as meriting better priority within the event of opposition for sources.[6]

Third, first-responders can be much more likely to address destructive environments. This will increase their want for bendy, adaptive structures (e.G., able to helping advert hoc or mesh networking in the absence of different supporting infrastructure). First-responders are probably to suffer from localized congestion: failures normally happen in particular places and at unique instances. The call for for all wi-fi services by means of all first- responders are probable to be concentrated in time and area, growing the peak-provisioning trouble.[1]

Finally, public safety system capabilities are nevertheless woefully insufficient, even as compared to the offerings available to industrial customers (e.G., 3G cell telephony v. Legacy LMR structures). The public safety network shares this conclusion.[2]

Public safety can't rely upon LMR designs "getting better." There is each the need and possibility to update outdated legacy infrastructure with leapfrogging generation to allow the wi-fi destiny wanted by public safety. Rather than preserve improvement of static, non-public, and expensive narrowband virtual LMR community infrastructures, public protection is in need of a community structure in which privateness, reliability, capability, adaptability and versatility are built in, no matter whose infrastructure their radios traverse, or even while infrastructure is broken or non-existent[4]. The destiny of public protection radios wishes to be a lot more adaptive and responsive to its surroundings (spatially, temporally, and situationally) to account for the more demands located on first responders. A public safety responder must be able to take his radio, his authentication and protection, his spectrum rights, and his precedence with him to any incident inside the united states, energy-up the radio, and be recognized and admitted to some thing incident command network he's legal to support.[9]

Table 1: Past, Present and Future for Public Safety Radios

	Past	Present	Future
Key characteristics of public safety radios	Proprietary, single user, single channel, single locale	Multichannel, trunked, narrowband (voice only) Regional Proprietary	Multichannel, multimedia (voice, data, integrated) National Open Interoperable Broadband (data) Mesh/Ad hoc
Shared infrastructure?	No. All dedicated to single user/department	Yes. Shared access infrastructure and base stations via trunking. Channels shared within trunk group but not otherwise.	Yes. Shared access infrastructure and radios. Pooling of spectrum for sharing among multiple trunked groups.

Shared spectrum?	No.	Channel sharing within trunk calling group only.	Yes. Sharing of spectrum across bands. Pooled spectrum.
Infrastructure/ Spectrum tied?	Yes. Closely coupled, closed systems. Limited interoperability via gateways, tying up additional spectrum	Yes. Spectrum still tied to infrastructure. Gateways used to link systems.	No. DSA facilitates unbundling of infrastructure and spectrum. Infrastructure shared across multiple bands.
CPE	Single channel radios	Multichannel radios	Multiband radios and flexible CPE

Table 1 summarizes our vision of the past, present, and future for public safety radio.

III. PUBLIC POLICY IS ON COURSE TO FACILITATE DSA IN PUBLIC SAFETY

Today's public protection radio systems are fragmented, overly high priced, beneath-capacitated, and limited. This is due, in part, to the legacy regime of dedicated, narrowband, and overly restrictive spectrum coverage. However, regulatory reforms including the consolidation of licensing eligibility, approving the certification of software radios, and permitting secondary trading for some certified spectrum reveal that progress is being made[9]. In comparison to the case for business wireless services that rely extra without delay on market-based totally methods, reform of public protection spectrum control will depend on non-marketplace establishments to coordinate cooperative evolution. Over time, a number of coverage reforms have helped to make spectrum pooling and DSA extra feasible in public safety applications.[6]

A. Cooperative role-and policy-based institutions are developing

The national system of Frequency Coordinators, the Regional Planning Committees (RPCs) and the introduction of the National Incident Management System (NIMS) within the National Response Framework (NRF) provide the institutional foundation needed to enable the transition to DSA and spectrum pooling.[3] These relatively new institutions are positioned to enable public safety managers to define global/local priorities, and static/dynamic rules and policies that can assist in self-regulation of spectrum use. The development of appropriate user-based prioritization and policies that reflect accepted practices in emergency management and incident response are essential to support developing CR and DSA technologies[5].

B. Regional Planning for Public Safety Band Management

Since its advent, the FCC has licensed public safety spectrum with the aid of segregating uses/customers into eligible and non-eligible categories on the way to manipulate radio interference. Eligible users compete for extremely small slivers of to be had spectrum. "The outcomes are: (a) a set of slim slots unfold in the course of the spectrum that users of various eligible classes cannot traverse; (b) a frame of incredible-high priced technologies designed to serve specific channel assignments; and (c) a patchwork of non-interconnected transmission centers serving unmarried-use licensees. Each user/licensee is pressured to build its very own infrastructure, and jealously guard its spectrum allocation and present licenses."[4] This fragmentation of the general public safety spectrum consequences in synthetic spectrum scarcity. As we talk below, the spectrum pooling concept will help correct this problem.[8]

In 1982, Congress supplied the FCC with the statutory authority to apply frequency coordinators to assist in developing and dealing with the LMR spectrum. Frequency coordinators are non-public agencies that have been licensed by the Commission to advise the most appropriate frequencies for candidates within the specific Part ninety radio offerings. In widespread, packages for new frequency assignments, adjustments to existing centers or operation at transient locations should encompass a showing of frequency coordination[2]. Although the FCC problems the real license, frequency coordinators carry out essentially all the spectrum acquisition activities on behalf of licensees. Each network of customers in the LMR bands has as a minimum one frequency coordinator entity this is owned and operated via its exchange affiliation, or inside the case of the Federal Government, with the aid of the Department of Defense (DOD).[9]

In the newer 700 and 800 MHz bands certain for public protection, the FCC has required that RPCs be shaped to create policy and prioritize makes use of for the band on a nearby basis. The RPCs should submit distinctive local plans to the FCC which are developed by way of consensus in every area, and which serve to pre-coordinate get admission to to the band for all eligible public safety entities in a vicinity[5].

The vital role of each frequency coordinators and RPCs is to organize the get admission to to spectrum in order that interference is avoided and communications desires (both present and destiny) are deliberate for and accommodated. Frequency coordinators and RPCs also perform the

treasured characteristic of communicating with existing licensees about plans for brand new facility creation and that they offer a valuable consensus and peer review characteristic. Additionally, RPCs can set up prioritization for the band via a consensus-based technique[8].

The RPCs and frequency coordinators are federally sanctioned and empowered, relied on local person-owned and controlled retailers who put into effect institution (pool) policies to manipulate spectrum and keep away from interference. If the RPCs have been authorized and empowered to enforce extra sizable and flexible rules that might be enforced via higher technologies, public protection spectrum management should move out of a spectrum shortage paradigm and right into a global wherein conversation was always available and portable throughout each geography and spectral bands[7].

C. NIMS and ICS Supply the Dynamic Cooperative Policy Framework

The recent adoption of the National Incident Management System (NIMS) and the Incident Command System (ICS) within the National Response Framework (NRF) provide an excellent working basis for the new paradigm for dynamic policy-based spectrum management. NIMS is a set of generic protocols for incident preparedness, management, response and recovery that all US first responders must conform to. NIMS includes the ICS, which defines the specific way incidents will be managed, from very small and local to major nationwide disasters. The ICS and NIMS include planning, response and recovery protocols for day-to-day, tactical and emergency activities.[4][10]

With national frequency coordinators managing knowledge of license rights granted in all bands across the nation, with RPCs empowered to create static regional prioritization rules and access protocols, and with the NIMS and ICS systems to ensure hierarchical consistency and to guide local layer dynamic prioritization and localized tactical network formation “on the ground,” the federal, state and local public safety communities have a significant amount of the institutional framework in place to enable public safety spectrum pooling.[9]

D. Transferring these developing incident management values to spectrum management is key to DSA development

Pooling can permit DSA/CR radios to opportunistically integrate narrowband channels to manual broadband get proper of entry to. Pooling gives no longer best a manner to get admission to spectrum without individual licenses, it creates the mechanism for spectrum rules to be authored, observed and transmitted to DSA/CR radios. Pooling is step one in dynamic spectrum manage[2].

To genuinely recognize the benefits of sharing on a huge, countrywide scale, standardized strategies within the course of sharing want to be advanced to simplify negotiating multilateral sharing agreements and to facilitate the layout and production of gadget that may take advantage of pooled bands. Standardized strategies are also important to allow customers to roam extra broadly, even nationally[9].

IV. SPECTRUM POOLING EXTENDS RADIO RESOURCES FOR INCIDENT RESPONSE

Pooling can allow DSA/CR radios to opportunistically combine narrowband channels to guide broadband get right of entry to. Pooling provides no longer quality a way to get admission to spectrum with out man or woman licenses, it creates the mechanism for spectrum policies to be authored, observed and transmitted to DSA/CR radios. Pooling is the first step in dynamic spectrum control[1].

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Enforceable restrictions on who gets to apply pooled spectrum and robust limits on what constitutes suitable secondary use are likely to be crucial. At the radio device level, there need to be technology and access guidelines/protocols that guarantee that the radio will research and confirm that spectrum is (1) accessible, (2) that get entry to is allowed (and the phrases governing such get admission to), and (three) that its use is appropriate (i.E., there isn’t a higher opportunity available). Additionally, the radio structures must encompass the functionality to signal/examine while conditions alternate (e.G., when the primary person needs to preempt/reclaim pool spectrum) and permit the radio to launch the spectrum when it is now not wanted or the radio is not allowed to use the spectrum.V This makes it feasible to permit the supposed use to dictate the great preference of spectrum usage, primarily based on elements including the radio environment and location (“I am underground”), the software (“I want to move video”), the incident (fire, typhoon, interstate pile-up, chemical spill).

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To completely recognize the blessings of sharing on a massive, country wide scale, standardized methods closer to sharing want to be developed to simplify negotiating multilateral sharing agreements and to facilitate the design and manufacturing of gadget which can take benefit of pooled bands. Standardized procedures also are important to permit customers to roam extra widely, even nationally[4].

A. Necessary Standardized Elements for Pooling

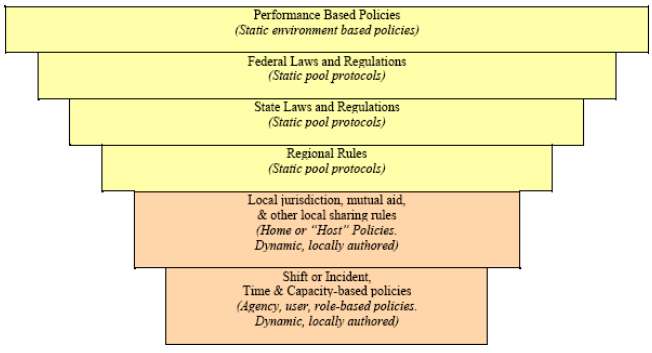
A number of core systems/elements will be needed to appropriately manage spectrum pool access and usage policies.[3]

1) Structured Pooling Policies

Spectrum get right of entry to rules are needed each for placing frequencies right into a pool, and for accessing them from a pool. Some regulations can be static, a few can be prevalent, and some may be dynamic or local. Some guidelines might also handiest be invoked in sure circumstances, and at certain places. Some static rules may be hard-coded into the CRs whilst they may be synthetic, at the same time as others can be downloaded periodically from a database. We envision a hierarchy of spectrum pool regulations, as a way to manual the radio to the first-rate preference for channel choice primarily based on its ability to clear up to be had options within a structure of guidelines[1].

Figure A below, represents a probable policy hierarchy for pooling and gaining access to spectrum. Once the radio learns the static rules that observe in any location, it could clear up dynamic person requests for spectrum based totally on extra situational rules, depending on such elements as the utility, the consumer's position inside the incident, or the growing incident command device as an incident grows and wanes[2].

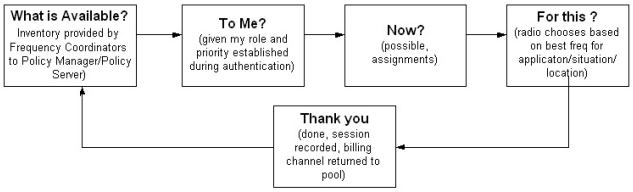
Figure A: Hierarchy of Pooling Policies



2) Policy Servers

Policy servers will be the number one "infrastructure" element of a DSA/CR radio network. Replacing radio gadget controllers, which control channel trunking and channel assignments in an LMR network today, policy servers will sit at multiple places in a community, along with the incident place to allow nearby incident command to difficulty specific regulations to responder radios (e.G., to installation a tactical community). As the radio powers up and authenticates, it asks the server for its policy replace, position, and tactical undertaking records as shown in Figure B under[11].

Figure B: How policies resolve



3) Embedded CR Technology

CRs ought to encompass suitable technology to allow them to "know" and "obey" DSA regulations. For some rules, in particular the most dynamic and vicinity/context structured, the CRs will need to realize their area and precise traits of the spectral environment in that area. Other policies can be hard-coded[4].

4) Policy Authoring Tools

Standardized coverage authoring gear are wanted so that it will permit flexible regulations to be designed and communicated to the radio infrastructure and executives. CR rules want to be rendered into suitable device readable formats and dispensed to the radios and the band managers. Moreover, any conflicts among policies want to be detected and resolved[7].

5) Policy Enforcement

To make sure that rules are observed, and that every one regulations co- exist without war or interference, a coverage enforcement machine might be required.

6) Portability of spectrum

A person must expect the capacity to roam together with his radio across programs, places, and networks. The ability for the radio to be served the satisfactory to be had channel for the consumer (primarily based on function and authentication), use (programs, together with broadband video, or sensor information), and region (I am supplying mutual useful resource to a network that isn't always my domestic base) is what we name spectrum portability. Our idea has critical variations from present day trunking practices. Today radio structures which can trunk channels, serve the subsequent excellent to be had channel to the person soliciting for a talk channel. However, that most effective works in the user's domestic radio system, where the radio is tough coded with get entry to to a constrained range of speak corporations, and the bottom stations are difficult coded to specific frequencies. Since a DSA/CR radio will now not depend upon tough coded

base stations, but will rather experience "white spaces" in a huge range of frequencies, it's going to, in concept, have the capability to transmit on any unused channel at any given time. Its choice about which channel to use could be determined not by way of difficult Coded statistics (having the "system key" mounted in these days's trunked machine architectures) however through understanding and following the coverage guidelines of the swimming pools for each band. A public safety DSA/CR radio will be "told" to get admission to simplest the general public safety spectrum pools. But the coverage servers and coverage enforcers, need to apprehend and authenticate this radio as a public protection radio, before it gets its coverage download[3]. This popularity and authentication have to be transportable throughout the state just like reputation and authentication of mobile phones is transportable across countrywide networks nowadays. Such portability will involve the improvement of roaming agreements between infrastructure proprietors, permitting get right of entry to to infrastructure assets, inclusive of policy servers, spine networks, switches, and frequencies.[8]

The pool managers ought to be vested with the potential to symbolize pool participants and devote pooled sources to binding mutual agreements among pool individuals and suppliers of community resources (consisting of infrastructure, extra secondary rights

to different pooled frequencies, and application services). This is necessary to save cash on transaction fees. It is impractical to assume person licensees to barter person agreements with every different. We believe that frequency coordinators are well positioned to control this top degree of DSA pool relationships and transactions[6].

V. OVERCOMING CHALLENGES TO SPECTRUM POOLING

Spectrum pooling and DSA represent elements of a cooperative spectrum control regime. This paradigm may be very exceptional from the prevailing "command and manipulate" approach that underpins spectrum allocations and rights these days. Because it's so extraordinary, the general public protection network and wireless stakeholders extra generally are not predicted to embody the idea, till it's been challenged and demonstrated powerful. Table 2 summarizes what we see as both real and perceptual demanding situations to spectrum pooling in public protection[12].

Table 2: Challenges for Spectrum Pooling in Public Safety
Real Challenges
Technology will not work as expected • Legacy services will work less well than with traditional technology • Prioritization will not work, Secondary uses not preemptible • Shared spectrum will have more congestion, less assured peak access than traditional model • Systems will fail to perform as predicted/promised
Government regulations will not permit • Necessary changes in regulatory framework will not occur • Political failure, Resistance of *status quo* vested interests
Early-adopter challenge • Pioneers face higher costs, lower benefits (network externalities) • Getting the adoption bandwagon started
Cost of NextGen Public Safety wireless systems • Learning, scale & scope economies accumulate over time, lowering costs • Managing cost recovery of shared systems • Incremental deployment and managing overlays
Perceptual Challenges
Risk of losing spectrum assets • Spectrum shared will not be reclaimable • Loss of ability to obtain additional spectrum allocations • Loss of control over radio networks

Systems will not be adequately reliable • Systems cannot be made robust (or as robust as legacy systems) • Cost of making systems adequately robust prohibitive for public safety radios • Systems will fail to meet standard of "worst case" planning which is necessary
Expanding pooling to wider communities • Sharing beyond narrow first-responder/public safety community infeasible, too risky

VI. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

The radio frequency spectrum will need to be shared tons extra intensively than has been possible with legacy technologies, enterprise fashions, and regulatory policies. A paradigm shift is vital to allow a wireless destiny of substantially multiplied wi-fi usage and superior competencies required by means of our records-primarily based economic system and society[6].

The want for this paradigm shift is specially acute inside the public safety community. The legacy regime critically limits interoperability among first responders and with the ones they need to talk with. The fragmentation of infrastructure into incompatible silo-based networks drives up costs, reduces available skills and capacity, and ultimately, harms the ability of public safety professionals to do their jobs[8]

The traditional technique of over-provisioning static community infrastructure to fulfill worst-case situation needs is neither possible nor proper. Luckily, it is also now not important. Dynamic Spectrum Access (DSA) technology like software program/cognitive radio (CR) are making it viable to share spectrum plenty extra intensively. Transitioning to a radio future of DSA/CR will allow radio systems to be an awful lot more bendy and adaptable to local situations. This will boom system capability and competencies, decorate interoperability and reliability, and could lower expenses[2].

While the wireless destiny is vibrant, getting there will not be easy. Coordinating the design, funding, and deployment of new technology without disrupting current operations may be difficult. Even if all of the considered necessary technology existed and had been commercially to be had at scale – that is a ways from the reality these days – we would want to reform enterprise fashions and spectrum management regulations to permit use of the technologies[5].

One crucial and essential first step toward constructing the wi-fi destiny is to transition to spectrum control primarily based on spectrum pooling. With pooling, public safety customers would extend their powerful get right of entry to rights and facilitate the adoption of DSA/CR wireless technology[3].

Significant progress has already been accomplished in the direction of organizing the institutional and policy-framework to efficaciously enforce the spectrum pooling idea. The National Response Framework (NRF), the National Incident Management System (NIMS), the Incident Command System (ICS), frequency coordinators and the Regional Planning Councils (RPCs) offer a number of the glue and apparatus had to coordinate and manipulate pooled spectrum. Essential additives (e.G., settlement on prioritization guidelines to control shared get right of entry to) nonetheless must be advanced and demanding situations overcome (e.G., mobilizing coordinated adoption of DSA/CR technologies) to progress alongside the direction to subsequent generation public safety verbal exchange systems[4].

[1]To maximize the chance of a successful transition, it will be critical to move incrementally. If public safety Specialists are to be convinced that spectrum pooling is indeed a idea whose time has come, they will want warranty that they may not experience any degradation in modern-day talents or lack of assets. Future progress will construct on early experience and studying. Over time, however, we anticipate the spectrum sharing idea to be customary. All destiny wi-fi systems must be greater dynamic and able to interacting with multiplied notions of precedence in spectrum get right of entry to rights. Public protection presents an essential first check case for commercialization of those sharing thoughts and achievement right here will supply superb externality advantages for the broader adoption of DSA/CR extra commonly[9].

VII. ENDNOTES AND REFERENCES

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