
Multimodal Computational Communication and Infrastructure Resilience in Digital Media Ecosystems: An Integrated Framework for Visual Analytics, Platform Interactivity, and Networked Dissemination

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KEYWORDS

computational communication, multimodal media, computer vision, platform interactivity, network infrastructure, communication security, digital dissemination.

ABSTRACT

Background: Computational communication research has moved from a niche methodological agenda to a foundational paradigm for studying digital media, platform behavior, visual representation, multimodal interaction, and large-scale communication systems (Van Attevelde & Peng, 2018; Matei & Kee, 2019; Trilling et al., 2024; Li et al., 2025). At the same time, contemporary communication environments increasingly depend on visual automation, computer vision, multimodal fusion, platform affordances, and algorithmically mediated participation across short-video, social media, and networked information spaces (Joo et al., 2019; Wu & Mebane, 2022; Guan & Zhou, 2022; Yu & Xu, 2021). Yet a major gap remains in linking these content-centered advances to the network infrastructure conditions that sustain reliable, secure, and scalable media communication, including routing design, host adaptation, and information security architecture (Tian, 2021; Zhang, 2022; Han et al., 2023; Zeng et al., 2025).

Objective: This article develops a unified research framework that integrates computational communication analysis, multimodal media intelligence, platform interaction research, and infrastructure resilience.

Methods: Using only the supplied references, the study conducts a conceptual, architecture-oriented synthesis. It brings together scholarship on computational communication theory, computer vision in media research, social platform use and continuance, computational propaganda, visual communication automation, multimodal representations, routing configuration, network convergence, passive optical LAN systems, and information security in institutional communication environments.

Results: The analysis indicates that computational communication should be understood as a layered system rather than a single methodological toolkit. At the upper layer, communication is shaped by visual representation, user interactivity, personalization, and multimodal affordances. At the lower layer, dissemination capacity depends on routing stability, network convergence, static-dynamic configuration logic, and secure information architecture. The findings show that the analytical future of computational communication lies in integrating media-content intelligence with infrastructural awareness.

Conclusion: A next-generation computational communication framework must move beyond content analytics alone. It should connect multimodal platform analysis with network-level resilience and institutional communication security. Such an approach offers a more complete understanding of how digital communication is produced, circulated,

INTRODUCTION

Computational communication has emerged as one of the defining intellectual developments in the study of media, digital platforms, and networked publics. Its rise has been driven by the recognition that communication in digital society is no longer fully intelligible through classical textual interpretation, small-sample manual coding, or purely qualitative observation. The scale, speed, heterogeneity, and platformization of contemporary media demand approaches capable of processing large datasets, tracking interaction patterns, interpreting visual signals, and linking behavior to technological systems (Van Atteveldt & Peng, 2018; Matei & Kee, 2019). More recent work has further emphasized that computational communication is not just a new method but an evolving research paradigm that combines theory, data infrastructures, multimodal analysis, and application practice across digital society (Trilling et al., 2024; Li et al., 2025; Zhong et al., 2023). This transformation has widened the scope of communication scholarship from message interpretation toward system-level analysis of how communication is produced, circulated, personalized, visualized, and governed.

A key feature of this shift is that communication objects themselves have changed. Media content is now deeply multimodal, highly interactive, and increasingly algorithmically organized. Short-video platforms, danmaku interfaces, trending search ecosystems, social robots, automated political visuals, and networked propaganda systems all operate through complex combinations of text, image, movement, metadata, interface affordances, user feedback, and infrastructural design (Song et al., 2021; Xiang & Chae, 2022; Sun & Liu, 2024; Huang & Chen, 2023; Minghua et al., 2024). Communication researchers are therefore confronted not simply with more data, but with differently structured data. The relevant communicative unit is no longer only a sentence, article, or broadcast clip. It may be a short video with embedded behavioral metrics, a nonverbal image sequence of political actors, a multimodal aesthetic construction of

national image, a personalized anchor-centered news segment, or a trending topic shaped by platform gatekeeping and visibility dynamics (Joo et al., 2019; Joo & Steinert-Threlkeld, 2022; Huang & Chen, 2023; Wu et al., 2021; Sun & Liu, 2024).

This reconfiguration has made computer vision and multimodal modeling central to the future of media research. Joo et al. (2019) demonstrated how computer vision and deep learning can support automated coding of televised leader displays and nonverbal political behavior. Joo and Steinert-Threlkeld (2022) more broadly argued for treating images as data in the analysis of political actors and events. Guan and Zhou (2022) identify computer vision technology as increasingly relevant to news communication research, while Wu and Mebane (2022) develop a deep learning framework for multimodal representations in vision-and-language tasks. Yu and Xu (2021) emphasize multimodal fusion as both an efficiency improvement and a research model for media communication. These studies collectively reveal that contemporary communication cannot be understood through text alone, because representation itself is now computationally visible, machine-readable, and multimodally structured.

At the same time, research on platform behavior has demonstrated that communication is shaped not only by representation but by user experience, interactivity, belongingness, personalization, and affordances. Xiang and Chae (2022) show that perceived interactivity influences continuous use intentions on danmaku video-sharing platforms through belongingness processes. Song et al. (2021) find that short-video applications can function as health information sources, with user experience, affordances, and continuance intention playing crucial roles in the sustained use of TikTok. Wu et al. (2021) show that personalization effects are reshaping mainstream media in short-video contexts. Ahmadi et al. (2023) demonstrate that content congruency shapes users' sharing behavior on social

media platforms. Qing and Yu (2022) reveal the importance of social support dynamics in Weibo communities around depression, while Sun (2023) studies the dissemination effect of popular science journals on WeChat through large-scale computational analysis. Taken together, these studies indicate that digital communication is increasingly organized around platform-specific conditions of interaction, emotional fit, personalization, and user participation.

Yet despite these advances, a major conceptual limitation persists in much of the current literature. Computational communication is often treated as though it begins and ends at the level of content, behavior, or platform interaction. Even when studies are sophisticated in their use of visual data, multimodal fusion, or large-scale social metrics, they frequently leave the underlying communication infrastructure undertheorized. This is a serious omission because digital dissemination depends not only on algorithms of visibility and user participation, but also on the stability, routing logic, host adaptation, convergence architecture, and security design of the networks across which communication travels. In other words, communication may be socially visible at the interface layer, but it is materially enabled at the infrastructure layer.

The infrastructure dimension becomes especially important when communication systems are embedded in institutional, scientific, or high-dependency environments. Tian (2021) discusses the application of passive POL networks in scientific research parks, indicating that communication environments are increasingly linked to specialized network architectures. Zhang (2022) addresses network convergence, routing, and host adaptation software technologies for switching systems, suggesting that interoperability and convergence are key concerns in complex digital environments. Yang and Yan (2021) discuss the configuration of next-hop logic in static routing, while Fang and Wu (2025) compare static and dynamic routing configuration. Han et al. (2023) propose a dynamic

addressing hybrid routing mechanism based on static configuration in ad hoc transit networks, and Ara et al. (2022) address parameter optimization in routing protocols for UAV ad hoc networks. Zeng et al. (2025) focus on network information security systems in scientific research parks, demonstrating that communication sustainability also depends on protection architecture. Even the patent-related item on static route configuration for logical routers points to the continuing relevance of routing design in networked digital systems (Nicira Inc., 2020). Although these references come from networking and security contexts rather than media studies proper, their inclusion reveals a broader truth: contemporary communication ecosystems are inseparable from the infrastructure that routes, secures, and stabilizes them.

This gap between upper-layer communication analytics and lower-layer infrastructure analysis is the central problem that motivates the present article. The supplied references offer a rare opportunity to bridge them. On one side, they document a maturing field of computational communication concerned with multimodal analysis, computer vision, computational aesthetics, social media sharing, propaganda, issue visibility, and platform behavior (Van Atteveldt & Peng, 2018; Joo et al., 2019; Joo & Steinert-Threlkeld, 2022; Huang & Chen, 2023; Ahmadi et al., 2023; Minghua et al., 2024). On the other side, they provide a compact but suggestive body of work on routing configuration, network convergence, passive optical LAN, network security, and institutional communication infrastructure (Tian, 2021; Zhang, 2022; Yang & Yan, 2021; Han et al., 2023; Zeng et al., 2025). Current scholarship has rarely connected these two levels systematically. As a result, communication scholars risk producing interface-rich yet infrastructure-thin accounts of digital communication, while network studies risk producing technically precise but communicatively abstract models of information flow.

The present article argues that these two domains should be conceptually integrated. Computational communication in digital society should be

understood as a layered system in which content, representation, participation, and visibility operate on top of routing, convergence, security, and network design. This layered view changes the analytical focus in several ways. First, it reframes multimodal communication not merely as a content challenge, but as a systems challenge. Second, it expands the concept of dissemination beyond audience exposure to include network path reliability and architectural resilience. Third, it brings institutional communication environments, such as research parks and high-capacity digital campuses, into dialogue with mainstream media and social platform research. Fourth, it allows computational communication to be interpreted not only as a method for studying digital society, but as a theory of how digital society is technically organized.

This reframing is especially important in the age of platform saturation and infrastructural dependency. The same digital environment that supports short-video health information and interactive danmaku belongingness also supports algorithmic gatekeeping, social robot aesthetics, visibility engineering, and computational propaganda (Song et al., 2021; Xiang & Chae, 2022; Huang & Chen, 2023; Sun & Liu, 2024; Minghua et al., 2024). Communication outcomes are therefore neither purely user-driven nor purely content-driven. They are shaped by multi-level conditions: platform affordances, multimodal form, personalization logic, visual automation, and backend network organization. Without an integrated framework, studies may explain engagement while ignoring infrastructure, or describe routing while ignoring mediated meaning.

The article therefore pursues three interrelated aims. First, it synthesizes the supplied literature on computational communication, multimodal media analytics, and digital platform behavior into a coherent upper-layer model of communication analysis. Second, it synthesizes the network and routing references into a lower-layer model of infrastructural enablement and resilience. Third, it develops an original integrative framework linking

these layers into a single account of digital media ecosystems. The resulting contribution is not an empirical dataset or algorithmic benchmark, but a publication-ready theoretical and methodological synthesis grounded strictly in the provided references.

A further motivation for this integration lies in the evolving role of institutions. Computational communication is often associated with public platforms and large-scale online discourse, but many of the same challenges now affect institutional communication systems such as research campuses, scientific parks, public information infrastructures, and secure digital work environments. These settings rely on communication technologies not only for interaction and dissemination but also for coordination, knowledge circulation, and risk management. In such contexts, security architecture, routing stability, and multimodal communication practices cannot be analyzed separately. Zeng et al. (2025) and Tian (2021) make this institutional dimension especially visible. Their work implies that communication research should not confine itself to public-facing apps or social platforms; it must also account for the infrastructural environments where professional and scientific communication occurs.

A final reason the present synthesis matters is that the field of computational communication is itself undergoing internal reflection. Li et al. (2025) review innovative paths in computational communication, emphasizing theoretical frameworks, research methods, and application practices. Trilling et al. (2024) similarly situate computational communication science within digital society, while Zhong et al. (2023) compare Chinese and English computational communication studies in terms of issues, methods, and theory. These reflections suggest that the field is mature enough to ask not only how to do computational communication research, but what kind of intellectual architecture the field requires next. This article responds to that moment by proposing that the next major step is infrastructural integration.

The central research question guiding the article is therefore: how can computational communication be reconceptualized as a unified system that integrates multimodal content analysis, platform interaction, and network infrastructure resilience? Sub-questions follow from this. What does the literature imply about the relationship between computer vision and communication meaning? How do interactivity, personalization, and congruency shape sustained platform use and dissemination? What role do automation, computational aesthetics, and gatekeeping play in visibility formation? How should routing design, convergence mechanisms, and information security be interpreted as conditions of communication, not merely of networking? And what kind of framework can unite these dimensions without collapsing one into the other?

By answering these questions, the article aims to make a dual contribution. Substantively, it offers a new framework for understanding digital media ecosystems as simultaneously representational and infrastructural. Methodologically, it demonstrates how seemingly heterogeneous references can be synthesized into a coherent line of inquiry. The broader implication is that computational communication research will become more complete when it not only studies what circulates and how people respond, but also how communication is technically carried, stabilized, and protected.

METHODOLOGY

This study employs a conceptual, integrative, and architecture-oriented methodology based strictly on the references supplied by the user. It does not introduce external literature, fabricate experimental data, or claim uncited empirical results. Instead, it constructs an original research framework by synthesizing two strands of scholarship that are usually examined separately: computational communication and media analytics on the one hand, and network routing, convergence, and information infrastructure on the other. The central methodological challenge is to show how these bodies of work can be interpreted as parts of the same

digital communication system.

The first guiding principle of the methodology is layered synthesis. The literature is divided analytically into two broad but interconnected layers. The upper layer concerns communication as visible and analyzable practice: user interaction, visual representation, multimodal messaging, computational propaganda, issue visibility, content congruency, personalization, and dissemination effects. The lower layer concerns communication as a networked infrastructure: passive optical networking, static and dynamic routing, network convergence, host adaptation, addressing mechanisms, and information security architecture. The rationale for this layered method is that contemporary digital communication is produced through both symbolic and infrastructural processes. A meaningful synthesis must therefore retain distinctions while also mapping dependencies.

The second guiding principle is function-centered interpretation. Rather than sorting the references solely by discipline or journal type, the study interprets them through the communication functions they illuminate. These functions include representation, interaction, visibility, dissemination, automation, routing, resilience, and security. For example, a study on danmaku platform interactivity is used not only as platform research but as evidence regarding participation and continuance mechanisms (Xiang & Chae, 2022). A study on static routing is used not only as networking research but as evidence regarding path determination in communication environments (Yang & Yan, 2021). This function-centered approach allows apparently distant references to be joined within a single analytical model.

The third principle is deployment realism. The article assumes that digital communication takes place in environments that are technically constrained, operationally structured, and institutionally situated. This means that platform affordances matter, but so do the infrastructures that sustain them. It also means that media

communication is increasingly embedded in specialized environments such as research parks, institutional platforms, and integrated digital systems, not only open social networks (Tian, 2021; Zeng et al., 2025). The methodology therefore emphasizes practical system operation rather than purely abstract conceptual analogy.

The fourth principle is multimodal continuity. Multiple references indicate that communication data increasingly combine text, image, audiovisual elements, and interaction traces (Joo et al., 2019; Joo & Steinert-Threlkeld, 2022; Wu & Mebane, 2022; Yu & Xu, 2021). The methodology treats this multimodality not as an add-on to classical communication but as a constitutive property of digital communication itself. Consequently, any framework built from the literature must explain how multimodal content is analyzed, circulated, and made visible.

The fifth principle is infrastructural accountability. A key intervention of the article is the insistence that communication theory must account for the conditions of network transport, routing logic, and security configuration. The networking references are not treated as tangential technical appendices. They are treated as evidence that communication cannot be sustained without path selection, system convergence, and security architecture (Fang & Wu, 2025; Han et al., 2023; Zhang, 2022; Zeng et al., 2025). This principle is what transforms the review from a standard media synthesis into a broader systems framework.

Within these principles, the methodological process proceeds through six analytical stages.

The first stage identifies the conceptual boundaries of computational communication as a field. Van Atteveldt and Peng (2018) establish that when communication meets computation, the field encounters opportunities, challenges, and pitfalls that extend beyond simple tool adoption. Matei and Kee (2019) frame computational communication research in a broader interdisciplinary data-oriented

context. Trilling et al. (2024) place computational communication science within digital society, and Li et al. (2025) review theoretical frameworks, research methods, and application practices. Zhong et al. (2023) compare Chinese and English computational communication studies, showing that the field has become international, plural, and reflective. These works collectively provide the metatheoretical basis for the present study. They justify treating computational communication not merely as a toolbox but as a scholarly field with evolving theory, methods, and applications.

The second stage maps the upper-layer communication environment. This stage focuses on content, visibility, and participation. Song et al. (2021) analyze short-video applications as health information sources, emphasizing affordances, user experience, and continuance intention. Xiang and Chae (2022) analyze perceived interactivity and belongingness on danmaku platforms. Ahmadi et al. (2023) examine congruency and sharing on social media. Wu et al. (2021) study personalization in mainstream media short-video programming. Sun (2023) investigates dissemination effects on WeChat using large-scale computational analysis. Qing and Yu (2022) analyze social support seeking on Weibo. Sun and Liu (2024) study issue visibility and gatekeeping actors in Weibo trending searches. Minghua et al. (2024) address computational propaganda against China, highlighting concurrency and selective incitement. These references are interpreted together as evidence that platform communication is shaped by a combination of interface affordances, algorithmic visibility, user attachment, emotional alignment, and dissemination logic.

The third stage maps the upper-layer representational environment, particularly its visual and multimodal dimension. Joo et al. (2019) show that nonverbal political behavior on television can be detected through computer vision and deep learning. Joo and Steinert-Threlkeld (2022) argue for image data as an object of automated content analysis. Jürgens et al. (2022) analyze age and gender

representation on German television computationally over time, reinforcing the importance of automated longitudinal visual analysis. Huang and Chen (2023) discuss the automation of visual communication and the aesthetic construction of national image via Twitter social robots. Guan and Zhou (2022) identify computer vision as increasingly applicable in news communication research. Wu and Mebane (2022) propose a deep learning framework for multimodal representations, and Yu and Xu (2021) present multimodal fusion as a model for communication research. These studies are used to establish that contemporary communication representation is machine-readable, visually structured, and computationally analysable in ways that classical media theory only partially anticipated.

The fourth stage introduces the lower-layer infrastructure environment. Tian (2021) on passive POL networks in scientific research parks indicates that communication environments rely on specific architectural designs for distribution and connectivity. Zhang (2022) on network convergence, routing, and host adaptation for FC switching systems points to the challenge of enabling heterogeneous systems to communicate effectively. Yang and Yan (2021) focus on next-hop configuration in static routing, while Fang and Wu (2025) compare static and dynamic routing configurations. Nicira Inc. (2020) suggests the continuing practical importance of static route configuration for logical routers. Han et al. (2023) propose a hybrid routing mechanism combining dynamic addressing with static configuration, and Ara et al. (2022) investigate performance enhancement in routing protocols for UAV ad hoc networks. Zeng et al. (2025) focus on network information security system construction in scientific research parks. Methodologically, these references are interpreted as evidence that communication dissemination depends on architectural rules of transport, address logic, path selection, convergence, and protection.

The fifth stage links these layers through a

dissemination-resilience model. This is the study's core integrative move. The model assumes that visible communication outcomes such as reach, sharing, personalization, issue visibility, or aesthetic influence are affected by upper-layer platform and content conditions, but that sustained and trustworthy dissemination also depends on lower-layer infrastructural resilience. For example, a computational communication study may analyze the spread of content on a short-video app, but the reliability of institutional communication or scientific media systems may additionally depend on network convergence, routing decisions, and secure transport. The literature does not provide a single existing model with this exact form, so the article builds it through systematic inference from the supplied sources.

The sixth stage develops an interpretive framework of four interacting dimensions: communicative affordance, representational automation, infrastructural routing, and security governance. Communicative affordance refers to interactivity, personalization, congruency, platform design, and social support dynamics (Song et al., 2021; Xiang & Chae, 2022; Ahmadi et al., 2023; Qing & Yu, 2022). Representational automation refers to the use of computer vision, multimodal fusion, and computational aesthetics in communication analysis and production (Joo et al., 2019; Joo & Steinert-Threlkeld, 2022; Huang & Chen, 2023; Wu & Mebane, 2022). Infrastructural routing refers to path configuration, network convergence, addressing, and transport organization (Yang & Yan, 2021; Fang & Wu, 2025; Zhang, 2022; Han et al., 2023). Security governance refers to system protection, institutional information security, and reliable digital communication environments (Zeng et al., 2025). The interaction among these dimensions forms the proposed integrated framework.

An important methodological feature of the study is comparative transfer. Some references are clearly media-centered, while others are clearly networking-centered. Rather than forcing them into the same vocabulary, the study transfers concepts

functionally. For instance, visibility in trending searches and path selection in routing are not the same phenomenon, but both concern selective flow in a system (Sun & Liu, 2024; Yang & Yan, 2021). Personalization in short-video media and host adaptation in convergence software are not identical, but both involve tailoring or compatibility mechanisms across system components (Wu et al., 2021; Zhang, 2022). This comparative transfer is used carefully and only to the extent warranted by the references.

Another methodological component is institutional extension. Much computational communication research focuses on public-facing media systems, but the networking and security references suggest that institutional communication environments deserve equal attention. The framework therefore extends computational communication theory into institutional infrastructures such as research parks, secure digital campuses, or technical communication environments. This extension is grounded in the references and avoids assuming that communication research must be limited to public social media.

Finally, the study adopts citation-grounded inference. Every major conceptual move is based on the supplied sources, either directly or through structured synthesis. Where the article proposes an original framework, it does so by logically combining cited lines of work rather than by making unsupported claims. The result is a rigorous conceptual methodology suitable for theory-building in a cross-domain area.

RESULTS

The central result of this study is the construction of an integrated framework that reconceptualizes computational communication as a multi-layered system composed of communicative affordances, multimodal representational automation, infrastructural routing, and security governance. From this main result, several more specific findings emerge.

The first result is that computational communication

is best understood not as a single methodological field but as a layered ecology of interaction, representation, and technical enablement. Foundational and reflective work in computational communication makes clear that the field includes diverse theoretical, methodological, and application-oriented concerns rather than one unified procedure (Van Atteveldt & Peng, 2018; Matei & Kee, 2019; Trilling et al., 2024; Li et al., 2025). When these references are interpreted alongside platform studies, visual media analysis, and infrastructure research, the field appears even more layered. Communication is produced at the interface level, mediated at the representational level, and sustained at the infrastructural level. This result challenges simplified understandings of computational communication as merely the use of big data or code in media studies.

A second result is that platform interactivity and user continuance are foundational to modern digital dissemination. Xiang and Chae (2022) show that interactivity shapes continuous use intentions via belongingness on danmaku platforms. Song et al. (2021) demonstrate that affordances and user experience support continued TikTok use as a health information source. Ahmadi et al. (2023) show that congruency affects sharing on social media platforms. These studies collectively indicate that dissemination in digital ecosystems is not driven by content exposure alone. It depends on the user's felt fit with the platform, the interaction environment, and the perceived relevance or harmony of the content. The integrated framework therefore places interactivity, belongingness, and congruency at the center of communicative flow.

A third result is that personalization has become a structural rather than peripheral feature of digital media communication. Wu et al. (2021) show that even mainstream media programming becomes personalized under short-video conditions. This is a highly significant finding in the integrated framework because it suggests that computational communication is not only about studying platform-native user behavior but also about the

reconfiguration of legacy media logics under digital distribution. Personalization thereby becomes a cross-cutting logic that affects both content design and dissemination pathways.

A fourth result is that visibility is increasingly produced through gatekeeping processes that are both computational and actor-driven. Sun and Liu (2024) show that issue visibility in Weibo trending searches depends on gatekeeping actors and public opinion events. Minghua et al. (2024) extend this broader concern by showing how computational propaganda operates through hidden concurrency and selective incitement. Together, these studies indicate that visibility in digital communication is not simply an emergent crowd phenomenon. It is structured, selective, and potentially strategic. In the proposed framework, visibility is thus treated as a system outcome shaped by platform logic, actor intervention, and communicative contestation.

A fifth result is that visual data are no longer ancillary to communication analysis; they are central communication evidence. Joo et al. (2019) demonstrate that televised nonverbal political behavior can be automatically coded using computer vision and deep learning. Joo and Steinert-Threlkeld (2022) explicitly frame image as data for automated content analysis. Jürgens et al. (2022) provide longitudinal evidence of how representation can be computationally tracked across television. Guan and Zhou (2022) further support the application of computer vision in news communication research. These studies jointly indicate that digital communication scholarship must now incorporate images, visual performance, and nonverbal displays as machine-tractable communication forms. The result is not merely technical expansion. It alters what counts as communicative evidence.

A sixth result is that multimodal fusion is becoming the default rather than exceptional mode of communication analysis. Wu and Mebane (2022) propose a deep learning framework for multimodal representations in vision-and-language tasks, while Yu and Xu (2021) describe multimodal fusion as

both an efficiency improvement and a research model for media communication. This suggests that communication analysis is moving from modality-specific pipelines toward integrated representational systems. The result has major implications for theory: communication is no longer most accurately represented as language plus supplementary imagery, but as multimodal composition from the outset.

A seventh result is that computational aesthetics and automated visual communication play a growing role in symbolic power and image construction. Huang and Chen (2023) show that automated visual communication and computational aesthetics shape national image construction through Twitter social robots. This indicates that aesthetics themselves can be algorithmically organized and politically consequential. In the integrated framework, representational automation is therefore not just a research method but also a communicative force. Machines do not only analyze images; they increasingly help produce symbolic visual order.

An eighth result is that dissemination studies on WeChat, Weibo, TikTok, and platform communities point toward a common model of communication as interface-conditioned circulation rather than simple broadcast diffusion. Sun (2023), Qing and Yu (2022), Song et al. (2021), and Sun and Liu (2024) all show, in different ways, that communication success depends on platform-specific community structures, support dynamics, visibility logics, and user motivations. The integrated framework interprets this as evidence that digital communication flow cannot be separated from the socio-technical form of the platform. This result aligns with but extends classical diffusion models by emphasizing interface and algorithmic conditions.

A ninth result is that lower-layer network architecture should be treated as a communication variable. Tian (2021) on passive POL networks, Zhang (2022) on network convergence and host adaptation, and Han et al. (2023) on hybrid routing in ad hoc networks collectively show that the

capacity of digital environments to support communication depends on architectural configuration. This may appear obvious from a networking perspective, but it is often neglected in media research. The present synthesis establishes that routing, convergence, and addressing are not merely engineering details. They influence whether communication systems remain stable, scalable, and interoperable.

A tenth result is that static and dynamic routing should be interpreted analytically as different models of communication path governance. Yang and Yan (2021) explain next-hop configuration in static routing, while Fang and Wu (2025) compare static and dynamic routing. Han et al. (2023) propose a hybrid model that combines dynamic addressing with static configuration. The conceptual result is that path determination in communication systems can be understood along a continuum from fixed predictability to adaptive responsiveness. Although these routing studies originate in networking, the article's integrative framework suggests that they illuminate broader questions about how digital communication pathways are stabilized or adapted under varying conditions.

An eleventh result is that security architecture is integral to sustainable communication ecosystems. Zeng et al. (2025) argue for network information security system construction in scientific research parks. In the integrated framework, this becomes a critical finding: communication environments cannot be understood through reach, participation, and visibility alone. They also require trust, protection, and resilience. This is especially important for institutional communication where data sensitivity, service continuity, and infrastructural reliability are central.

A twelfth result is that institutional communication environments deserve a more prominent place in computational communication research. Many media studies focus on public platforms, but the infrastructure references indicate that communication in research parks and specialized

digital systems is equally worthy of analysis (Tian, 2021; Zeng et al., 2025). This result broadens the field and suggests that computational communication should study not only public discourse but also technologically dense institutional ecosystems.

A thirteenth result is that communication resilience emerges from the interaction of upper-layer and lower-layer conditions. A platform may have strong user engagement but weak infrastructural support. Conversely, a system may have robust routing and security but low communicative vitality. The integrated framework shows that durable digital communication requires both symbolic effectiveness and infrastructural resilience. This is perhaps the most important substantive result of the article.

A final result is that the future of computational communication likely lies in infrastructural reflexivity. Reflective accounts of the field already emphasize theory, methods, and challenges (Van Atteveldt & Peng, 2018; Li et al., 2025; Trilling et al., 2024). The present synthesis adds that the field should now become more explicit about the technical infrastructures on which communication depends. Doing so does not dilute communication research. It makes it more complete.

DISCUSSION

The results developed above carry important implications for both computational communication theory and the broader study of digital society. The most immediate implication is that communication scholarship can no longer afford to treat infrastructure as invisible background. Digital communication has often been analyzed at the level of messages, users, platforms, or visibility outcomes, but the present synthesis demonstrates that these levels are materially dependent on routing, convergence, host adaptation, and security architecture. In other words, communication is not only socially mediated and algorithmically curated; it is also path-configured and infrastructurally maintained. This point may seem self-evident from a

networking standpoint, yet it remains underdeveloped in communication research. The article therefore argues for what may be called infrastructural reflexivity: an awareness within computational communication that the field's objects of study are inseparable from the systems that transport and stabilize them.

A second implication is that multimodality must be theorized not only as a property of content but as a condition of communication power. Many studies acknowledge that images, videos, texts, and interactions are combined on platforms, but the references show a deeper transformation. Computer vision can detect political nonverbal displays, longitudinal representation biases, and aesthetic constructions of national image, meaning that the visual layer is both communicatively active and analytically formalized (Joo et al., 2019; Jürgens et al., 2022; Huang & Chen, 2023). Multimodal fusion frameworks show that representation is increasingly processed as integrated cross-modal structure rather than as separate channels loosely combined (Wu & Mebane, 2022; Yu & Xu, 2021). This suggests that communication power in digital systems increasingly operates through the ability to coordinate modalities effectively, and research must keep pace with that shift.

A third implication concerns the relationship between platform psychology and dissemination. Studies on belongingness, continuance intention, congruency, and social support indicate that digital communication succeeds not merely by being available or visible, but by being affectively, relationally, and experientially inhabitable for users (Xiang & Chae, 2022; Song et al., 2021; Ahmadi et al., 2023; Qing & Yu, 2022). This means that dissemination cannot be reduced to exposure metrics alone. It is anchored in user–platform fit, emotional resonance, and interaction design. The article's framework therefore proposes that communication studies should view dissemination as a socio-technical achievement produced jointly by content, interface, and user orientation.

At the same time, the discussion of issue visibility and computational propaganda suggests that not all dissemination is benign or neutral. Visibility can be strategically engineered, selectively amplified, and weaponized through platform dynamics (Sun & Liu, 2024; Minghua et al., 2024). This observation complicates celebratory narratives of digital participation. It implies that computational communication must study both user-centered engagement and system-centered manipulation. A platform that fosters belonging can also foster selective mobilization. An algorithm that enhances visibility can also suppress alternative issues. Thus, the integrated framework advanced here is not simply a harmony model. It is also a model of tension between participation and control, openness and selectivity, visibility and governance.

The infrastructural layer sharpens this tension further. Routing systems, convergence architectures, and security frameworks are often presented as neutral technical solutions. Yet they shape which communication paths are stable, which systems are interoperable, which institutions are protected, and which failures are tolerated. Static routing offers predictability but limited adaptability; dynamic routing offers flexibility but may introduce complexity; hybrid mechanisms seek compromise (Yang & Yan, 2021; Fang & Wu, 2025; Han et al., 2023). These are technical design questions, but they also have communicative implications. A communication system with rigid paths may be stable but brittle. One with fully adaptive paths may be flexible but difficult to govern. The article suggests that these infrastructural trade-offs deserve more direct theoretical attention in media studies, especially where communication continuity is institutionally important.

This leads to a broader insight: digital communication is increasingly a matter of system design rather than only message design. In older communication paradigms, the emphasis often fell on rhetoric, framing, narrative, or audience interpretation. These remain important, but the present synthesis shows that contemporary

communication also depends on design decisions about interface affordances, visual automation, multimodal integration, network convergence, and security governance. This does not erase classical communication concerns; rather, it embeds them within more technologically intensive environments. The communicative act is now often a designed event within a larger socio-technical architecture.

The study also has implications for how communication scholars approach institutional environments. Research parks, scientific campuses, and secure digital ecosystems have not traditionally occupied the center of computational communication theory. Yet the supplied networking and security references reveal that these sites are communication-intensive environments with their own routing, convergence, and protection needs (Tian, 2021; Zeng et al., 2025). This suggests that the future field should not be limited to studying public-facing platforms like TikTok, Weibo, or danmaku systems, even though these remain highly important. It should also examine institutional communication infrastructures where resilience, host adaptation, and security are crucial to knowledge circulation and organizational coordination.

A significant theoretical benefit of this expansion is that it helps correct a bias toward interface visibility in digital media research. Communication scholars often study what can be easily observed: posts, likes, videos, comments, trending topics, and visual displays. Infrastructure remains less visible and therefore less discussed. But invisibility does not imply unimportance. In fact, the less visible the infrastructure, the more powerfully it may condition the communication environment. The article therefore argues that a mature computational communication science should analyze the visible and invisible layers together.

The integration advanced here also invites methodological reflection. A possible objection is that the networking references and media references belong to different intellectual traditions and may not be meaningfully synthesized. This objection is

understandable. One set of studies examines media content, user behavior, and visual meaning, while the other examines routing configuration, convergence software, and network security. Yet the synthesis does not claim they are identical. It claims they are interdependent. Communication studies have long drawn on psychology, sociology, political science, and informatics without collapsing their distinctiveness. The present article extends that interdisciplinary habit to infrastructure studies in a more explicit way.

Another possible objection is that the move toward infrastructural analysis could distract communication scholarship from meaning, culture, and interpretation. This concern deserves serious consideration. However, the article's framework does not replace symbolic analysis with technical analysis. It adds a layer of explanation. Meaning still matters. Belongingness, support seeking, visibility, aesthetics, and propaganda remain central. The argument is simply that these phenomena are increasingly mediated by platform and network conditions that cannot be left analytically unexamined. Far from diminishing interpretation, infrastructural awareness can deepen it.

A third possible objection is that the lower-layer references are relatively sparse compared with the richer upper-layer literature. This is true, and it marks a limitation of the current evidence base. The article therefore proceeds cautiously, drawing conceptual rather than overly granular operational conclusions. It does not claim to offer a complete network theory of communication infrastructure. Rather, it uses the available references to show that such a direction is both plausible and necessary.

Several limitations of the present study should be acknowledged more explicitly. First, the article is conceptual rather than empirical. It does not provide a newly collected multimodal dataset, routing simulation, or security audit. Its contribution lies in framework construction. Second, the reference set itself is heterogeneous in language, genre, and disciplinary depth. Some references are clearly

theoretical or reflective, while others are application-specific or technically narrow. This diversity is productive for synthesis but also limits the precision of some cross-domain claims. Third, the networking references focus largely on routing and institutional architecture rather than on consumer media infrastructures specifically. This means that some of the article's system-level interpretations are necessarily inferential rather than directly observed within mainstream social media platforms.

Despite these limitations, the future research potential is considerable. One clear direction is empirical work that studies how multimodal communication outcomes vary across different infrastructural environments. Another is research on institutional communication systems that combines media analytics with routing and security analysis. A third is theoretical refinement of dissemination as a multi-layer concept involving visibility, interactivity, path reliability, and protection. A fourth is comparative work across cultural contexts, building on Zhong et al. (2023), to understand how computational communication develops differently across linguistic and national traditions. A fifth is the systematic study of social robots, computational aesthetics, and propaganda not only as content phenomena but as phenomena dependent on infrastructural support and resilience (Huang & Chen, 2023; Minghua et al., 2024).

There is also an important normative implication. If communication systems are infrastructurally conditioned, then questions of equity, access, resilience, and governance become part of communication ethics. A platform with strong multimodal engagement but weak security or unreliable routing may expose users and institutions to risk. Conversely, a technically secure system with poor interface design may fail to support meaningful participation. The integrated framework suggests that responsible communication design requires attention to both expressive richness and infrastructural stewardship.

A final and more speculative point concerns the

evolution of computational communication as a field identity. Reflective references already suggest that the field is moving from method adoption toward theoretical maturity (Van Atteveldt & Peng, 2018; Li et al., 2025; Trilling et al., 2024). The present article proposes that infrastructural integration may be one of the next defining steps in that maturation. A field that can analyze visual representation, short-video interaction, algorithmic visibility, routing architecture, and security systems within one conceptual space will be better equipped to explain digital society than one confined to any single layer.

CONCLUSION

This article has argued that computational communication in digital media ecosystems should be understood as a layered system linking multimodal content analysis, platform interactivity, representational automation, infrastructural routing, and security governance. Drawing strictly on the supplied references, it has shown that contemporary communication research already contains strong upper-layer analyses of social platforms, short-video use, belongingness, congruency, visibility, computational propaganda, computer vision, and multimodal fusion (Song et al., 2021; Xiang & Chae, 2022; Joo et al., 2019; Wu & Mebane, 2022; Ahmadi et al., 2023; Sun & Liu, 2024). It has also shown that lower-layer work on passive optical networking, routing configuration, convergence software, hybrid addressing, and institutional security provides indispensable insight into how digital communication environments are sustained and protected (Tian, 2021; Zhang, 2022; Han et al., 2023; Zeng et al., 2025).

The core conclusion is that computational communication can no longer remain interface-centered if it aims to explain digital society adequately. It must account for the infrastructures that carry, stabilize, and secure communication flows. This does not reduce communication to networking. Instead, it enriches communication analysis by showing how symbolic visibility and material transport are intertwined. A second

conclusion is that multimodality and computer vision have transformed what counts as communicative evidence, making visual and nonverbal data central to communication scholarship. A third conclusion is that digital dissemination depends not only on exposure but on interactivity, personalization, congruency, support dynamics, and platform-specific affordances. A fourth conclusion is that secure and resilient communication environments, especially in institutional settings, require routing and information-security awareness that communication studies have too often left implicit.

Taken together, these conclusions suggest a future direction for the field: infrastructurally reflexive computational communication. Such a framework would study not only who communicates, what circulates, and how audiences respond, but also how communication is technically routed, converged, adapted, and secured. In an era when digital communication is increasingly embedded in platform ecosystems, institutional networks, and multimodal data environments, that broadened perspective is not optional. It is necessary for a fuller understanding of communication itself.

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