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A Dynamic Network-Based Approach to the Analysis of Basketball Team Coordination and Tactical Adaptation

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Abstract. The performance of basketball teams relies not only on the skills of the individual players, but also on the interaction and coordination between the players. Traditional performance measures are not necessarily a good reflection of the evolution of player relationships and tactical structure in a match. This research aims to suggest a dynamic network based approach for the analysis of basketball team coordination and tactical adaptation. Players are nodes in the network and passing relationships are modeled as a connection that changes over time. Interactions patterns and changes in players' role are analyzed through three aspects: network density, node centrality and network structural change. The framework is then put into practice on three theoretical scenarios: half-court offense, high pressure defense and when the offense is making a transition. Comparative theoretical analysis examines how various tactical scenarios can call for varying interaction patterns and coordination strategies. The analysis emphasizes that neither network stability nor tactical flexibility is of primary importance, and that network changes must be understood in the context of the game. This framework can serve as a conceptual basis for future studies with actual match data, which will explore connections between dynamic network structure and the performance of basketball players.

Keywords: Dynamic Networks, Basketball, Team Coordination, Tactical Adaptation, Network Analysis

1. Introduction

Basketball is a complicated team game where the performance depends not only on the individual skills, but also on the coordination and interaction among players. While playing, the teams keep changing their passing and receiver formations and offensive/defensive strategies as the game evolves. These interactions constitute a dynamic system which the role of each player and the relationship between players can change over time [1]. It is essential to consider these changes in order to explain how teams coordinate and adjust their play depending on the competitive environment.

The traditional methods of basketball analysis primarily involve examining individual and team metrics like points, assists, rebounds, and shooting percentages. While these indicators can be informative of performance, they may not adequately reflect the ways in which teams are coordinated with one another and the changes in structure [2]. While static network analysis can

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describe the relationships amongst players it has shortcomings in representing the continuous evolution of the relationships throughout a game [3]. Hence, another way of looking at the game of basketball that might be beneficial is to take a dynamic network approach that sees players and their interactions as an ever-changing network.

The aim of the study is motivated by the researchers' desire to investigate how variations in the networks of cooperation among players point to tactical adaptations and team coordination in different game scenarios. Specifically, patterns of interactions and coordination needs could vary depending on the type of offense, defense and transition. A breakdown of these situations can be used to help understand how the teams can continue to work well together whilst changing the roles of the players and the passing patterns when the tactical requirements vary. However, a change in the network should not be assumed to be a performance improvement and the importance will depend on the competitive environment and the reason for the tactical change.

In this study, theoretical modeling approach by dynamic network analysis is taken. Players are modeled as network nodes, and passing relationships and other observable cooperative interactions as connections between nodes. Key indicators of interaction patterns and their change over time are network density, node centrality, and structural change. These indicators are then used to analyze 3 representative scenarios of games to compare the level of coordination, role distribution and tactical flexibility. The study does not use complicated algorithms but applies basic mathematical modelling and comparative theoretical analysis to create an easily understood framework to understanding team dynamics.

2. Theoretical foundation

2.1. Basketball dynamic networks

Network analysis is a good method for looking at the connections and interactions between components of a complex system. In basketball, players can be nodes, and passing relationships, as well as other cooperative actions, can be nodes or connections between nodes [3]. The resulting network illustrates the relationships among players during a game and how their individual performances relate to the overall team.

While static networks are a representation of relationships for a given time, dynamic networks will show changes in interactions over time. In basketball, passing frequency, player involvement, and passing pattern of interaction might differ based on offense schemes, defensive pressure and transition between offensive and defensive phases. This allows us to model these relationships as a series of network structures, enabling us to analyse the development of team organisation during a game.

In particular, there are three characteristics of a network that are relevant to the analysis of basketball. First, the network density is an indicator of the overall degree of interaction between players. Secondly, node centrality is useful for determining players' positions on the interaction structure which are important. Third, network structural change refers to how network relationships change from one period to the next. These attributes are combined to form a baseline for analysing the development of team structures, and how team interaction is linked with tactical changes.

2.2. Team co-ordination and tactical adaptation

Team Coordination: The ability to coordinate team play towards common goals. In basketball, coordination is the passing, positioning, role sharing, and timing of offense and defense [4]. While

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individual skills are crucial, team performance is also influenced by the ability of players to link their movements and react to other players in their team and on the opposite side.

Tactical Adaptation: When making changes to team formations and/or player actions as the game situation evolves. For instance, a team can pass the ball around when the main ball handler is put under stress. In the transition of attack, players can quickly adjust the relationships between each other in order to take the opportunities. The changes suggested that not only does team coordination need not be preserved even when team members maintain fixed relationships, but it also may need to be adjusted through changes in the interaction network [5].

There are two complementary aspects of team organization; network stability and tactical flexibility [6]. A stable network can be used to maintain a stable level of cooperation and predictability of roles, while a flexible network can be used to react to unforeseen situations. But too much stability can restrict tactics and too much change in structure can throw off the coordination that has been developed. Hence, the stability vs flexibility must be viewed in the light of the tactical goals and not as a given preference for either stability or flexibility.

Based on these views, this study views basketball team coordination as a dynamic process and regards player interaction and contextual requirements as the key factors that influence team coordination. Dynamic network analysis offers a way to describe structural changes, and a theoretical scenario analysis to explain how these changes may relate to tactical adaptation. The theoretical underpinning for the mathematical modelling and comparative analyses presented in the sections that follow.

3. Dynamic network construction and structural metrics

3.1. Dynamic network construction

In this study, a basketball team is modeled as an evolving network [7] to study the changes in player interactions over the course of a game. Players are considered nodes and the passing relationship between them is considered a directed connection. The direction of a connection reflects the direction of a "pass" and the weight of a connection represents the number of passes between two players in a time period.

The network at time (t) can be represented as $(G_t=(V,E_t,W_t))$, where (V) denotes the set of players, (E_t) represents the connections between players, and (W_t) describes the corresponding interaction weights. Since player interactions change throughout a game, the network is updated across consecutive time windows, producing a sequence of network structures rather than a single static representation.

This way the analysis can reflect the evolution of connections, the roles of important players and how interactions are dispersed throughout the team. A central player, for instance, might be the player who gets the ball more often in regular play and then be less dominant when the opposition puts the pressure on. These changes form the basis for analysing the response of team organisation to the various tactical requirements.

3.2. Key network indicators

The structural features of the dynamic network are described by means of three indicators.

First of all, network density is an indicator of the overall level of interaction between players. With a passing network, the more dense it is, the more distributed the interactions are across the number of potential links among players. But the increase in density doesn't automatically translate

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to improved performance; the basketball tactics might be just as important, with some sort of passing lanes and roles clearly established.

Secondly, the centrality of nodes will be used to identify players who are important in the network. To keep it simple, this study concentrates mainly on weighted degree centrality, indicating the amount of overall interaction strength of a player. These are the strengths of the passing network: Outgoing Strength is the percentage of the player's passing involvement and Incoming Strength is the percentage of times that the player receives passes. If any of these measures change, it could mean that the responsibility of the organization is shifting or players are changing.

Third, network structural change refers to the extent of the difference between the interaction structure of successive time windows. Can be expressed as the difference between two consecutive adjacency matrices:

$$R_t = \frac{\|A_t - A_{t-1}\|_F}{\|A_{t-1}\|_F + \varepsilon}$$

where (A_t) and (A_{t-1}) are the weighted adjacency matrices for consecutive periods, $(|\cdot|_F)$ denotes the Frobenius norm, and (ε) is a small positive constant that prevents division by zero. A larger value of (R_t) indicates a greater change in passing structure. This measure describes structural change rather than tactical success, which must be interpreted in relation to the game situation.

These indicators, when viewed as a whole, offer complementary pieces of information related to team organization. The density of the network indicates the general interaction pattern, the centrality of nodes indicates the distribution of player participation and the change of structure indicates how these interactions have changed over time.

3.3. Team coordination evaluation

No single network indicator can capture team coordination. A team can have a lot of interaction, but be very dependent on one player. On the other hand, a team with fewer connections could be very cohesive if the passing structure and the role of the players is suitable for the tactical goal. Hence, interaction structure, role distribution and adaptability to change should be taken into account when evaluating coordination.

Team coordination is explored in this study using a combination of network density, player centrality, and structural change. An increase in density can inform about the width of interaction, centrality about the concentration or dispersion of the organizational responsibilities, and structural change about a reorganization or not of the network. These indicators are not combined into a numerical score, but are considered together.

Coordinative stability and tactical adaptability are proposed as distinguishing features of the proposed framework. Patterns of interactions may indicate a stable cooperation, whilst structural changes may be interpreted as a reaction to changes in the defensive pressure or to new opportunities for attacking the goal. But both stability and change are not necessarily good. Their relevance is based on the tactical requirements of a specific situation, and the network structure observed.

In this study, the three network indicators are therefore applied as analytical tools to compare the different basketball scenarios. The next section will discuss half-court offense, high-pressure defense

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and offensive transitions, and how the roles of the players and the need for coordination can vary in each situation.

4. Scenario based theoretical analysis of tactical adaptation

4.1. Scenario one: half-court offense

Half-court offense involves the players maintaining their movement and creating good offense in a fairly organized half-court set. In this case, the dynamic network can be used to show the organization of the passing relationships and the distribution of responsibilities between players [1]. Network density gives a measure of how wide the players interact, and node centrality can be used to identify who the main organisers are in the offensive structure.

A central playmaker can be used to start a series of passes and set up movement. This kind of structure can ensure clear distribution and uniform performance of the roles. But if the offense relies too heavily on one player, when that player is tight man covered, it could leave the offense in trouble. A more distributed interaction structure, on the other hand, can offer alternative passing options, and involve multiple players in the initiation of offensive actions [1].

In a dynamic network, it does not always make sense to strive for the highest possible network density to make an effective half-court offense. What is instead important is if the structure of the interaction is conducive to the desired offensive plan. A shift in centrality could mean a shift in player responsibilities, and relatively stable passing relationships could mean that an offensive pattern is stuck. This study was an observation that offers theoretical grounding for the association between network structure and coordinated offensive play.

4.2. Scenario 2: high-pressure defense

When the pressure is high, that can blow up the flow and prevent major offensive players from being in the game. If the main ball handler is receiving a lot of pressure, the team might want to switch off who passes to them, find another way to pass, and get more people on the ball. The changes in node centrality and network structure can be analyzed to understand such adjustments [8]. For instance, if the centrality of the main playmaker tends to decline and the centrality of some other players increases, this might be a sign of a shift in the function of organization. Other passing relationships can develop as the other players support each other or offer other lanes to pass through. In this instance, variations in the network could indicate an effort to coordinate in a self-defensive configuration.

But more interaction does not necessarily mean a more successful response. Players under pressure may also rush passes or look for the less effective pass – and as a result, make structural changes without impacting offensive results [8]. Thus, network indicators should be used in conjunction with the tactical situation. The central theoretical issue is whether the team can reorganise its interaction structure in such a way as to maintain co-ordinated action under the pressure from the outside.

This is an example of the benefits of a flexible network configuration. Teams that aren't as dependent on specific skills/offensive responsibilities and have other ways to attack the ball could have greater opportunity when other aspects of their offense are thrown into disarray. However, the benefits of this flexibility will relate to the abilities of the players, the tactical approach of the team and the defensive scheme used by the opposition.

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4.3. Scenario 3: offensive transition

Offensive transition refers to the rapid changes in player roles and positions that occur when possession changes hands. In such situations, players typically lack the time to dribble leisurely or seek out advantageous positioning. Consequently, as players shift roles and look for new opportunities to advance the ball, the network of on-field interactions can undergo rapid changes during the game [9]. In this case, some of the network structural change can be used to explain the rate of change of passing relationships between successive periods of time. Adjustments in node centrality could also help to identify shifts in who is initiating or supporting the transition. A player, for example, who gets the ball right after a defensive rebound might suddenly be the hub of the attack, with other players forming new links in the attack.

However, network change rate is not necessarily a good measure of transition efficiency. A significant change in structure can indicate an effective fast break or simply be caused by poor movement or pass attempts. Whether this new pattern of interaction is going to be useful to the team in its ongoing goals is a matter of tactical significance. The theoretical relevance of this situation is the connection between speeding up adaptation and coordinated action. Successful transitions need players to be able to transition into different roles and be able to coordinate enough to take advantage of that temporal opportunity.

4.4. Comparative analysis across scenarios

All three scenarios show that basketball teams have varying coordination requirements based on the tactical situations. The half court offense is primarily about set pieces and having defined roles. When the defenses are tight, passing lanes must be changed and roles shifted. Offensive transitions focus more on speed of the transition and the coordination of the changing positions. These differences imply that there is no optimal network configuration for all game situations. The network's structure can either be rather stable for an organized offense or more flexible to allow a team to react to the defense or maximize transition opportunities. Likewise, in some cases centralized interaction patterns might be more effective in decision making, while in other cases with limited primary organizer, distributed interaction patterns might be more effective. Thus, the association between network form and team coordination needs to be interpreted as conditional.

5. Conclusion

This study aims to develop a dynamic network-based model for analyzing basketball team coordination and adaptation. The study focuses on the structure of the network, analyzing network density, node centrality, and structural change in the time frame of the half-court offence, the high-pressure defence and the offensive transition. The theoretical analysis emphasizes on the need for coordination stability and tactical flexibility. There might be different interaction structures and role distributions in different game situations, which means that the team coordination should not only be measured based on the indicators of their individual networks. It is suggested that the proposed framework can be used in future research to analyze real match data to further explore the relationship between dynamic network structure and basketball performance.

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